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TECHNICAL REPORT #26

APPLICATION OF A FORMAL SYSTEMS METHODOLOGY TO CIVIL DEFENSE

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This report contains the studies which treat various problems concerning disaster mitigation and civil defense with the formal methodology of systems, the HOS methodology. Included are restricted inquiries concerning transportation, communication and goals analysis. The more extensive results present (1) an integrated host and risk area system for relocation, using relocation of industrial personnel as a test bench for the applicability of HOS methodology to a problem which is a general one; (2) a specification of place as a data

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type and a primitive or basic operation for locating one object in relation to another, which are prerequisites for dynamic mapping, planning, and implementation of mitigation systems.

The results obtained indicated that the HOS methodology can be employed in the design of systems pertinent to the mitigation environment. Evidence for this conclusion includes (a) the design of an integrated system using stated goals and available information; (b) the description of the system includes inputs, outputs, and functions in natural language utilized by planners, operators and participants in the mitigation environment; (c) the integrated system includes some clear cut requirements which the HOS staff finds absent in the current treatments of mitigation and nuclear war preparedness planning; (d) the methodology can be used to capture very fundamental operations which are common to a variety of problems which appear only on the surface to present quite different difficulties; (e) the design included provision for the beginning of defining surge, the transition to activation of plans and execution of plans.

In addition to these studies, HOS, during the tenure of the contract, also carefully considered what specific recommendations can be made to enhance disaster mitigation planning and execution on the basis of its experience with the system and its environment.

The most important direct finding, however, is that by employing the HOS methodology, it should be possible to design testable systems for a variety of responses to a variety of crises and disasters. The methodology is rigorous enough to deal with the enormous difficulties in terms of complexity and uncertainty and to retain sufficient flexibility to respond in real time to changing situations.

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SUMMARY

This report contains the studies which treat various problems concerning disaster mitigation and civil defense with the formal methodology of systems, the HOS methodology. Included are restricted inquiries concerning transportation, communication and goal analysis. The more extensive results present 1) an integrated host and risk area system for relocation, using relocation of industrial personnel as a test bench for the applicability of HOS methodology to a problem which is a general one; 2) a specification of place as a data type and a primitive or basic operation for locating one object in relation to another, which are prerequisites for dynamic mapping, planning, and implementation of mitigation systems.

The results obtained indicate that the HOS methodology can be employed in the design of systems pertinent to the mitigation environment. Evidence for this conclusion includes (a) the design of an integrated system using stated goals and available information; (b) the description of the system includes inputs, outputs, and functions in natural language utilized by planners, operators and participants in the mitigation environment; (c) the integrated system includes some clear cut requirements which the HOS staff finds absent in the current treatments of mitigation and nuclear war preparedness planning; (d) the methodology can be used to capture very fundamental operations which are common to a variety of problems which appear only on the surface to present quite different difficulties; (e) the design included provision for the beginning of defining surge, the transition to activation of plans and execution of plans.

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SECTION I

INTRODUCTION AND RECOMMENDATIONS

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This investigation was concerned with examining the applicability of a formal system methodology, the HOS methodology to the civil defense environment. After a period of learning, the HOS staff attempted modest design efforts. These efforts were extremely importatnt in proceeding to the more interesting and demanding design work. Using industrial relocation as a test bed, an integrated system was designed and a detailed description of an important data type, place, was completed.

To our knowledge, this is the first time that a formal methodology with the characteristics of the HOS methodology has been employed in the civil defense environment. On the basis of our experience, crucial issues such as identifying important information, sequence and priority of activities, decision making and identification of possible performance indicators are the most obvious benefits from using the HOS approach. These benefits are achieved using natural language and thus the approach can be used by planners.

The integrated system for relocation specifically deals with the major issues and provides for correct interfaces. The work dealing with the description of the data type place is an example of how a very basic notion common throughout the civil defense environment, can be defined. The detailed definition is provided to provide FEMA with a rigorous account of how such basic definitions are achieved.

Finally, it weems worthwhile to provide a few modest recommendations based on our experience with these design efforts.

I. A systematic treatment allows FEMA to pull together very diverse functions and problems. We recommend application of such an approach to fully utilize the expertise available in FEMA.

II. Once a goal has been selected, support the plan for that goal with a visible and systematic route, showing inputs, outputs, functions, and connections between parts of the system very clearly.

III. Subject plans in hand to a systematic examination, using experience with disaster response to aid the systematic examination.

SECTION II

CONSIDERATION OF SOME GOALS FOR DCPA

CONSIDERATION OF SOME GOALS FOR DCPA

This paper concerns the goals of a DCPA system based on material thus far examined by HOS and a visit to Region 1. It seemed appropriate to describe some goals at this time so that as the various system characteristics of civil defense become evident and then defined by HOS methodology, it would be feasible to investigate how well they were defined and how, in general, certain of them interface in DC systems in general. In addition, as various goals for CD become apparent and the resources and operations required for them become identified, it will be possible to relate various separate goals in a consistent way, thus providing a degree of versatility for systems, and to identify goals which are inconsistent or redundant.

It is also apparent both from the historical record [1] and legislative support of civil defense [2] that goal setting in regard to civil defense is a policy decision, made by elected officials, seemingly a process quite apart from the technical ones. It must be recognized, however, that in the case of civil defense technology and political decision making, i.e., should we have a civil defense system and what it should do, are not distinctive. Civil defense can be considered a passive measure of defense, focusing on the saving of lives in the case of war or disaster. In the case of war, the battle at Waterloo can be regarded as the last instance in which the population and their resources were not regarded as "combatants." Subsequently, as the role of the individual soldier became increasingly supported by technology, the industrial and economic base capable of supplying the technology and thereby waging war became combatant and targets of value. Thus, in addition to and perhaps in some instances only secondarily [3], is the saving of "civilian" lives and resources a process carried out for humanitarian reasons. In fact, the population is required to participate to varying degrees to support achievement of military objectives. Thus, a decision to have a civil defense system, given the current means by which war and attacks are carried out, can be a decision to attempt to protect, defend, and recover military capability. In the case of the United States, the war of 1812 was the only instance in which the threat directly affected the population; in the modern era, the entire country can be regarded as threatened in a very direct way. An attack solely on purely military targets, if that were tactically possible, would not eliminate completely the defensive and offensive abilities of the nation. Accordingly, HOS has examined and considered goals described in the literature to determine if the goal of civil defense had been or can be clearly defined. Without a clear statement on this matter, the technical issue of designing a system or examining proposed or existing systems cannot be effectively addressed.

For example, if the goal is to save lives, the system would possess features which would specifically reduce fatalities. If the goal is to save lives and provide a means to recover the national welfare, the addition of whatever follows the "and" affects how and under what circumstances resources are directed to save lives along particular constraining lines. Regardless of what follows, the "and", whether explicitly or implicitly given, in effect defines the system directed at its achievement. The technology of systems in the case of civil defense evolves and is to a great extent an extension of the political decision. Indeed, as we progress in our work on modeling civil defense systems, determination of what happens to be inputs given stated constraints will aid those vested with the responsibility of political decision making. An example of a current instance where technology and politics merge is in the search for secure and trustworthy ways to monitor Soviet and U.S. compliance with arms limitation agreements.

The Federal Civil Defense Act of 1950 (as amended) aims at protection of life and property against enemy attack. The definition of protection as far as DCPA is concerned does not extend to measures for recovery, but rather is the apparent responsibility of other Federal agencies. The definition of attack is now broader than in 1950.

The following list of goals for a CD system have been extracted from a variety of sources. They are not mutually exclusive and assume that both the U.S. and at least one potential adversary have the military capability in number of warheads, launchers, reliability of weapon performance, and accuracy cited in the literature [4,5,6].

Goals:

1. minimize fatalities in a nuclear war [7].
2. to provide a U.S. counter to an adversary CD operation (e.g., crisis relocation) to be used in crisis negotiations (the bargaining chip goal) or reflection of gravity of situation [1].
3. to offset a fatality disparity between U.S. and adversary (equalize hostage taking) [1].
4. to enhance or maximize war-fighting (defend and win) effort (live to fight, survive to win [3].)
5. to project a firm image of resolve to Allies [8].
6. to provide reduction in fatalities due to radiation resulting from nuclear war not involving U.S. in other areas of the world [1].
7. to reduce fatalities and provide means of recovery for survivors of a nuclear war [1].
8. to protect sufficient size of population to provide option for "limited nuclear" war [9].
9. to protect lives and property from natural and man-made disasters [10].
10. to protect lives and property from terrorist threat [1].
11. to protect lives and property from effects of long-term economic and other non-violent crises, e.g., fuel embargo [1].
12. to protect lives and property in the event of an "accidental limited" nuclear attack on U.S. [1].

Inspection of this short and hardly exhaustive list of goals prompts mention of at least two rather simply stated schemes to achieve goals 1,7,8,12 and to some extent, 2,3,6. Both schemes may be considered difficult or unrealisitic to implement:

I. Adversary and U.S. disarm or limit both nuclear and conventional forces [11,12].

II. In the event of a threat to use nuclear devices, which is considered likely to be implemented by an adversary of the U.S., the U.S. or adversary concedes to demands or "surrenders" [13].

Scheme I is not expected for some time. Scheme II appears unacceptable to U.S. or adversary because of the loss of national identity and/or loss of its ability to project its power and protect its interests. Scheme II appears to represent an option likely to be taken only when all other options are unavailable.

This exercise then has led to the notion that CD may have goals in addition to or other than reduction of fatalities. In the absence of implementation of Scheme I (an entirely reasonable solution), Scheme II remains as the only option left to maximize survival and minimize fatalities. It can be argued that a CD system which is prepared to minimize fatalities during an attack allows, at best, a chance to "win" and at worst delays the time and degrades conditions of "concession" or "surrender."

It must be emphasized that these considerations do not necessarily require that DCPA alter its charter, but does suggest that it is worth considering what other systems such as defense and recovery to achieve a defined condition of survival might interface with DCPA systems and how such interaction would be achieved on the part of DCPA.

Analysis of the current system of civil defense indicates that a maximum of 70% of the U.S. population would be fatalities in an adversary nuclear attack [14,15]. Data drawn from a study concerned with survival of relocated population of the U.S. after a nuclear attack have indicated the extensive and deleterious effects of radiation on population and food supply and the uncertainties surrounding the issues of where and how great the radiation from fallout might be [16]. A conservative consideration of the data from [16] tends to increase the number of projected fatalities from [14,15] and leave unanswered the issue of survival [15]. The current system would appear to require considerable improvement over many years to reduce fatalities and enhance survival [15]. To relate reduction of fatalities and enhancement of survival to other goals, HOS is in the process of a study of data and analysis of survival of industry and other elements.

To date, there is no evidence available to HOS indicating that goals 2,3,8 have sufficient value relative to others listed to warrant equivalent priority in systems design. Some goals would be achieved as a by-product of other goals. Some students of US security have suggested that Soviet CD reflects a philosophy concerning war-fighting [4] yet the US Secretary of Defense did not appear to value the effectiveness of the soviet program to "enhance the prospects for Soviet society as a whole following any full-scale nuclear exchange. . ." [8].

Given the presumed inferior status of current US CD (70% fatalities) vs the potential adversary program (15-10%) [14],one might expect this issue to be negotiated or for the US to upgrade its CD effort. But, thus far, the public record is devoid of reports indicating the bargaining value of CD. To what extent CD maneuvers, such as crisis relocation would be important in crisis negotiations is not clear [15],but given the presumed perception of the potential adversary as reflected in "best" Soviet CD, a US CD related to war-fighting (i.e. increasing survivors who have resources to defend) would be a better candidate than one devoted to reduction of fatalities.

The distinction between reduction of fatalities and enhancement of survival has bearing on system features. For example, a study of feasibility of CR [17] has indicated that certain urban populations would relocate up to 100 miles distant from their cities. Time, fuel, and population burdens were considered carefully to minimize fatalities. In a study concerned with survival of the relocated population [16], it was indicated that to bring food and population closer, relocation would have to involve much greater distances than 100 miles. It can be argued that, as the population exhausted its carried food supply [16] at its relocated site, it would subsequently move in a second relocation to approach new food supplies. The second relocation might not be feasible under certain circumstances, such as in the aftermath of an "all out" nuclear attack. This would degrade survival and increase fatalities. The issue as to what extent reduction of fatalities and survival enhancement can be complemented without compromising either.

Consideration of this example focuses attention on system features which provide interfaces between recovery (or survival support) systems and DCPA systems, a problem recognized on a somewhat different basis by others [18].

As noted here, however, systems for reduction in fatalities and enhancement of survival may be closely related to a "war fighting" goal, requiring inter-action of DCPA systems with defense measures, a requirement that has not been recognized in a recent reorganization plan [18]. It remains to be determined to what extent such interfaces would enhance deterrence, given the absence of schemes I and II, or provide the basis for a deterrence of a second order.

Goals 9-11, while not related to large-scale catastrophic environments as in the case of the other goals, are concerned with events with a slightly greater probability of occurring. Given the DCPA charter and the involvement of regional offices in localities, the current system appears to have considerable potential for providing approaches to these goals.

Thus far, HOS definitions of resources and operation suggest common features for systems devoted to goals 9-11 and others listed. The more subtle unique features of systems devoted to large-scale catastrophic events are being identified using a similar approach.

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SECTION III

GEOGRAPHICALLY-DISTRIBUTED SYSTEMS

IN

HIGHER ORDER SOFTWARE

1.0 Crisis Relocation: The Need for a Specification of "Place"

Crisis relocation involves the transfer of people and resources from one place to another in anticipation of either man-made or natural disaster. Such a transfer can be represented mathematically as a function CR that maps "states of the U.S." to "states of the U.S.," where a "state of the U.S." is a table of correspondences between places, population, and resources. For some purposes, only portions of these tables may be needed, involving correspondences between places and population, places and oil, places and food, and so on. We might also want to have an allocation function that tells us what the population and resources are at a given place in a particular "state of the U.S." This mode of representation is illustrated in Figure 1.

2.0 Specification vs. Implementation of "Place"

The intuitive notion of place is illustrated in Figure 2. A place, to a first approximation, is a well-defined (geometrically) non-empty region in two-dimensional space. In Figure 2, places are defined in terms of a grid superimposed on a map of the U.S. If each such region is given a unique name, then tables of the sort illustrated in Figure 1 can be straightforwardly constructed. Note that the naming scheme itself is arbitrary; while numbers are used in the implementation of the notion place in Figure 2, they are not assigned in any particular order or pattern. Patterns of various kinds may be chosen for one reason or another, but these are then propoerties of the specific implementations in which they occur, rather than characteristics of the notion place itself. .

The purpose of specifying a notion like place independently of implementation is to characterize what it is about all the implementations of such a notion that make them implementations of that notion. Whatever properties of specific implementations of place, for example, are not relevant to their being places, but only to their exemplifying a particular

a) $us' = CR(us)$

WHERE us, us' ARE STATES-OF-THE-US

b) us =

place 1	population 1	food 1	water 1	oil 1	. . .	steel 1
⋮	⋮	⋮	⋮	⋮	⋮	⋮
place n	population n	food n	water n	oil n	. . .	steel n

c) population table =

place 1	population 1
⋮	⋮
place n	population n

food table =

place 1	food 1
⋮	⋮
place n	food n

--- steel table =

place 1	steel 1
⋮	⋮
place n	steel n

d) (population, oil,..., steel) = Allocation (us, place)

Fig. 1: (a) Crisis Relocation as a Function From States of the US to States of the US;
(b) States of the US as Tables of Correspondences Between Places, Population, and Resources;
(c) Subtables Representing Correspondences Between Places and Components of States of the US;
(d) Allocation Function: Population and Resources at a Given Place in a Particular State of the US.

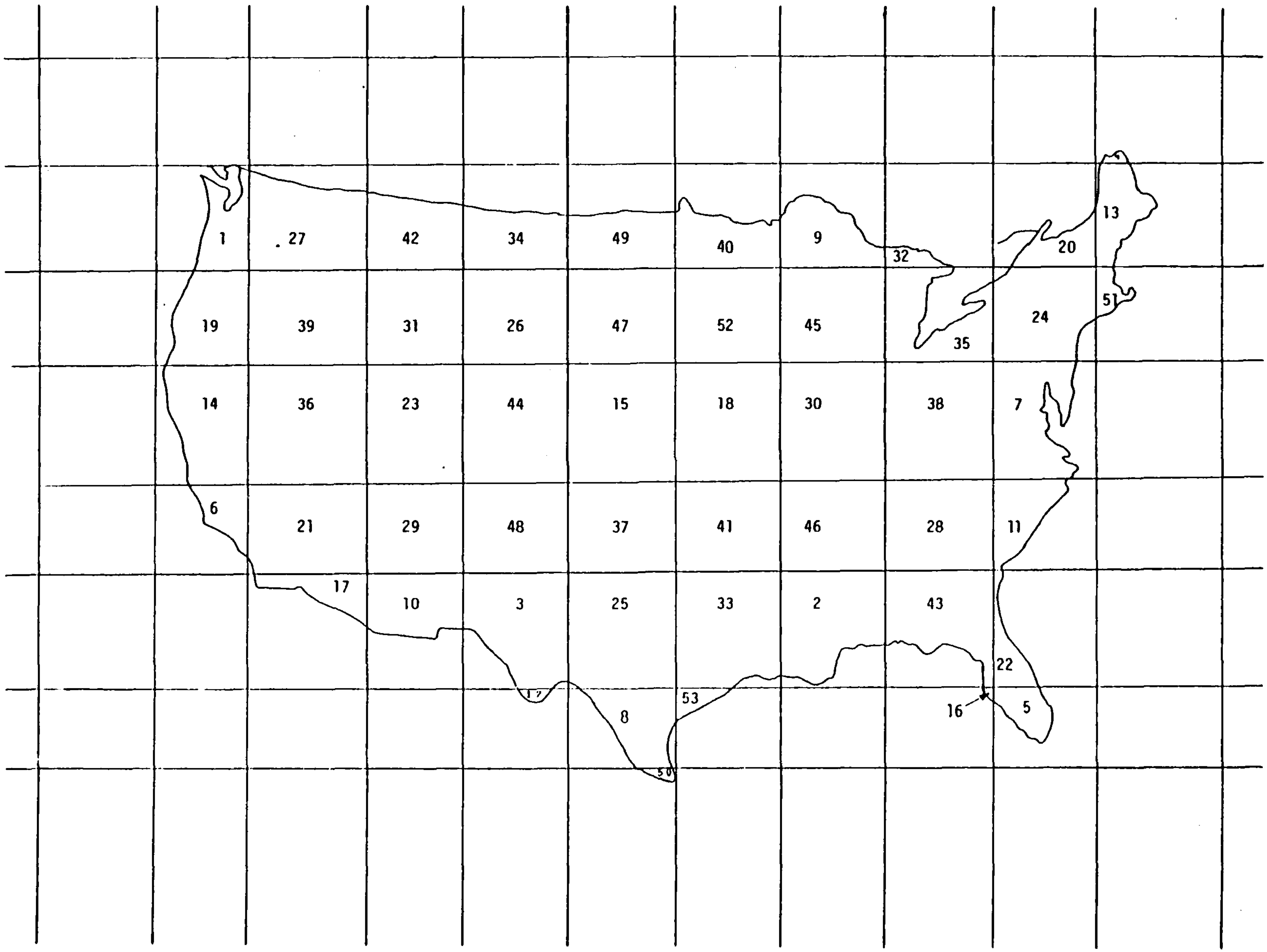


Fig. 2 One Implementation of the Notion Place

subclass of places, are not included in the specification of place. In the case of place, the minimal set of properties that seems to be required in the specification is provided by the four cardinal directions. Given any place in a geographically distributed system, we can always travel from that place to one that is north, south, east, or west of it. This is the property of place that we adopt here as providing an abstract characterization of that notion.

3.0 HOS Specification of "Place": First Approximation

An initial HOS specification of data type PLACE is given in Figure 3. North, south, east and west are formalized as primitive operations that map places to places. The essential constraints on the behavior of the primitive operations - - i.e., what it is about them that qualifies them as formalizations of the four cardinal directions - - are given in the form of axioms, which are in this case eight in number. The first four axioms in Figure 3 stipulate that the members of each pair North/South and East/West constitute inverse operations; the last four axioms stipulate that the members of each pair North/East, North/West, South/East, South/West are orthogonal. The first axiom, for example, says that the place that is immediately north of the place that is immediately south of some place is that place itself, while the last axiom says that we get to the same place from a given place whether we travel first one place south and then one place west or first one place west and then one place south.

4.0 An Implementation of "Place"

Figure 4 illustrates one way in which the example in Figure 2 can be interpreted as an implementation of the specification in Figure 3. The table in Figure 4 assigns to each of place in Figure 2 immediate northern, southern, eastern, and western neighbors, thus providing

DATA TYPE: PLACE;

PRIMITIVE OPERATIONS:

$place_1$ = North ($place_2$);
$place_1$ = South ($place_2$);
$place_1$ = East ($place_2$);
$place_1$ = West ($place_2$);

AXIOMS:

WHERE p IS A PLACE
North (South(p)) = p;
South (North(p)) = p;
East (West (p)) = p;
West (East (p)) = p;
East (North(p)) = North (East(p));
East (South(p)) = South (East(p));
West (North(p)) = North (West(p));
West (South(p)) = South (West(p));

END PLACE;

Fig. 3 HOS Specification of Data Type PLACE - First Approximation: The Four Cardinal Directions

PLACE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
NORTH		46	48		22	14	24	25		29	7	3	4	19	47	43	21	52	1		36	11	31	20	37	34	
SOUTH	19		12	13			11	50	45		22		51	6	37			41	14	24	17	5	29	7	8	44	39
EAST	27	43	25			21		53	32	3		8		36	18	5	10	30	39	13	29		44	51	33	47	42
WEST		33	10		16		38	12	40	17	28		20		44			15		32	6	43	36	35	3	31	1

PLACE	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
NORTH	38	23	45	42		41		32	39	15	35	27		18		28	26	9	30	49	44		8	13	40	33
SOUTH	43	10	46	23	35	53	26	38	21	25	28	36	52	33	31	16	48	30	2	15	3	47			18	
EAST	11	48	38	26	20	2	49	24	23	41	7	31	9	46	34	22	15	35	28	52	37	40			45	
WEST	46	21	18	39	9	25	42	45	14	48	30	19	49	37	27	2	23	52	41	26	29	34		24	47	8

Fig. 4 Figure 2 Interpreted as an Implementation of Figure 3

definitions of the four primitive operations, as required by Figure 3. The specific assignments, furthermore, are constructed in such a way that all of the axioms in Figure 3 are satisfied. Place 23, for example, gets place 31 as its immediate northern neighbor and place 31 gets place 23 as its immediate southern neighbor; this verifies the first axiom in Figure 3 for the value p = place 23. Place 23, similarly, gets place 29 as its immediate southern neighbor and place 44 as its immediate eastern neighbor, while place 48 is both the immediate eastern neighbor of place 29 and the immediate southern neighbor of place 44; this verifies the sixth axiom in Figure 3 for the value p = place 23. The other assignments in Figure 4 are also easily verified as satisfying Figure 3 in the same way. Note that the table in Figure 4 provides one interpretation of Figure 2 as an implementation of Figure 4, but not the only such interpretation. Figure 4 corresponds to the most intuitively straightforward interpretation in which North, South, East, and West are taken to correspond respectively with up, down, right, and left, but other correspondences between these two sets of directions are also possible, depending on the requirements of the situation. Note also that the gridwork provides a highly idealized form of implementation for the specification in Figure 3. Irregularly shaped regions can also be used to implement this specification as long as the four primitive operations representing the cardinal directions are guaranteed to be always single valued.

5.0 Problems With the First Appoximation: The Need for Border Regions

There is still one discrepancy between Figure 3 and Figure 4, however, as illustrated by the gaps in the assignments in the latter. While Figure 3 accounts adequately for the directionality of a geographically distributed system, it makes no provision at all for border regions, i.e., regions with one or more expected neighbor missing. The specification in Figure 3, though adequate for infinitely extended regions with no external borders, is deficient for the more normal case in which external borders are included, such as Figure 2.

The absence of border regions not only is intuitively unnatural, but also precludes the construction of useful operations and structures, such as the operation in Figure 5. The control map in Figure 5 defines an operation that tests whether or not one place is north of another. OR and COJOIN in the figure are HOS control structures: OR indicates an alternative determined by the indicated binary conditions and JOIN denotes sequence; COJOIN is a generalized version of JOIN in which the sequential operations share some variables.* As the figure indicates, the operation inputs two places, p_1 and p_2, and outputs a boolean b, which is True if p_1 is north of p_2 and False otherwise. First the immediate northern neighbor of p_2 is found and named p'. This place p' is then tested against p_1; if they are equal b is True and the process stops. If p' is not p_1, then p' is tested to see whether or not it is a northern border. If p' is a northern border, then b is False and again the process stops. If p' is not a northern border, then the entire process repeats with p' as the second input instead of p_2. Eventually, after enough repetitions, the process stops with either True or False as the value of b.

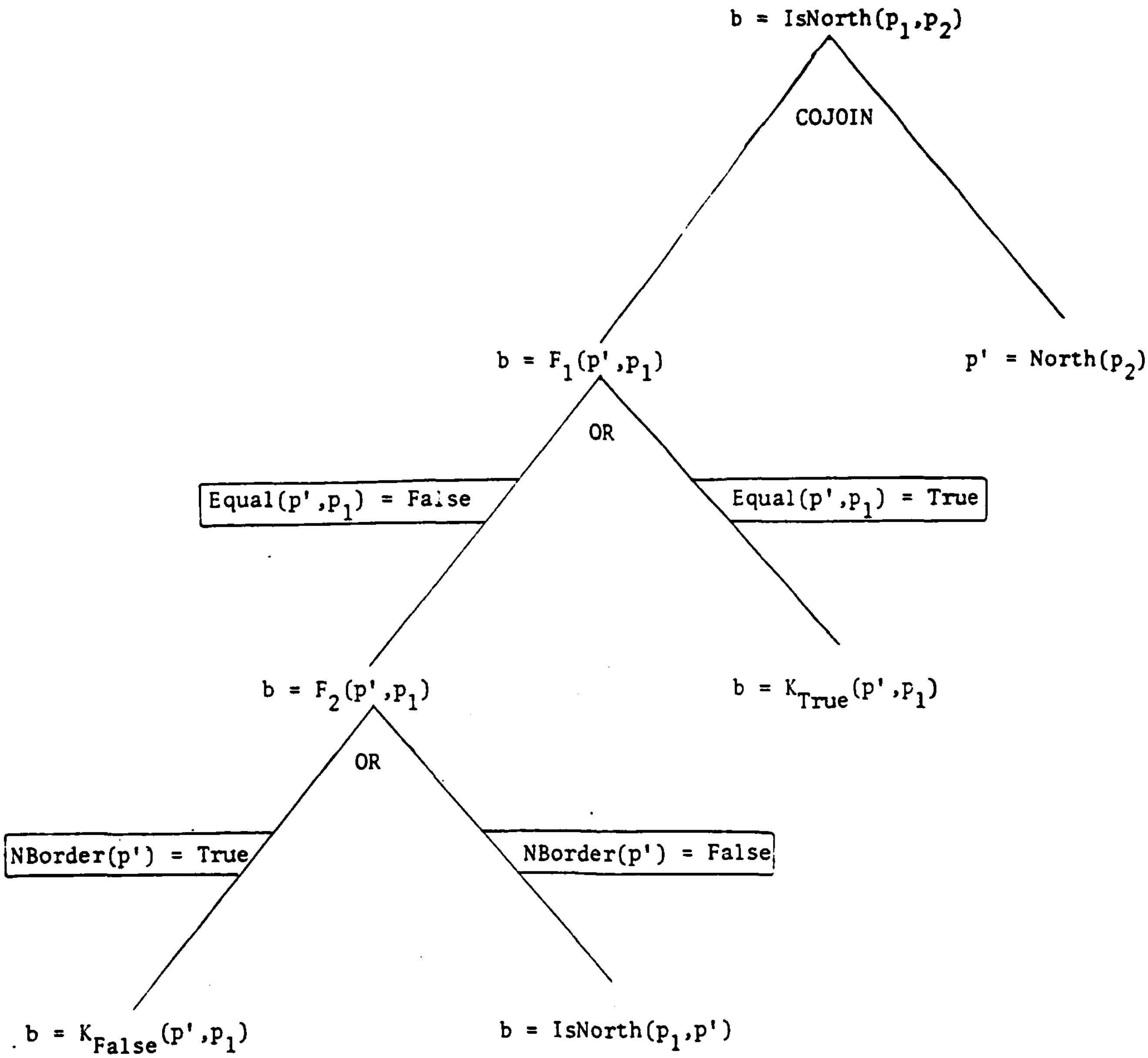
The problem with this operation, of course, is that we have thus far not given any meaning to the operation NBorder, which appears in the condition of the lowest OR. We have interpreted NBorder intuitively as meaning "is a northern border," but we have not characterized what this means formally, as we did for the four direction operations, for example.

6.0 HOS Specification of "Place": Second Approximation

One way in which we might incorporate border regions is given in Figure 6. Each axiom in Figure 6 corresponds to one of the axioms in Figure 3,

* "Techniques For Operating System Machines", TR-7, Higher Order Software, Inc., Cambridge, Massachusetts, July 1977.

OPERATION: boolean = IsNorth($place_1$,$place_2$);



i.e., $b = \begin{cases} \text{True, if } p_1 \text{ is North of } p_2 \\ \text{False, otherwise} \end{cases}$

Fig. 5 <u>Operation That Tests Whether One Place is North of Another</u>

```
DATA TYPE: PLACE;

PRIMITIVE OPERATION:
place2 = North (place1);
place2 = South (place1);
place2 = East  (place1);
place2 = West  (place1);
boolean = NBorder (place);
boolean = SBorder (place);
boolean = EBorder (place);
boolean = WBorder (place);

AXIOMS:
   WHERE p IS A PLACE;
North (South(p)) = 1p or KREJECT (2p);
East (South(p)) = South (East(1p)) OR KREJECT (2p);
West (South(p)) = South (West(1p)) OR KREJECT (2p);

PARTITION OF p IS
   1p| SBorder (p) = False,
   2p| SBorder (p) = True;

South (North(p)) = 3p OR KREJECT (4p);
East  (North(p)) = North (East(3p)) OR KREJECT (4p);
West  (North(p)) = North (West(3p)) OR KREJECT (4p);

PARTITION OF p IS
   3p| NBorder (p) = False,
   4p| NBorder (p) = True;
East  (West(p)) = 5p OR KREJECT (6p);
North (West(p)) = West (North(5p)) OR KREJECT (6p);
South (West(p)) = West (South(5p)) OR KREJECT (6p);

PARTITION OF p IS
   5p| WBorder (p) = False,
   6p| WBorder (p) = True;
West  (East(p)) = 7p OR KREJECT (8p);
North (East(p)) = East (North(7p)) OR KREJECT (8p);
South (East(p)) = East (South(7p)) OR KREJECT (8p);

PARTITION OF p IS
   5p | EBorder (p) = False,
   6p | EBorder (p) = True;

END PLACE;
```

Fig. 6 HOS Specification of Data Type PLACE - Second Approximation: The Four Cardinal Directions Plus Border Regions except that the order has been changed to group axioms according to which partition they involve. The partitions are based on the four new primitive operations that define the notion of border: northern border, southern border, eastern border, and western border. Again places are assumed to be discrete, distinguishable entities. The number of places is unspecified; there can be as few as one or as many as desired, depending on how one chooses to implement the data type. As in Figure 3, each place is assumed to have a unique immediate northern neighbor, a unique immediate southern neighbor, a unique immediate eastern neighbor, and a unique immediate western neighbor.

A single place may be two or more kinds of borders at the same time, depending on the circumstances and the implementation they require. In Figure 2, for example, place number 6 is both a southern border and a western border, while place number 4 is a northern border, an eastern border, and a western border. Place number 12, however, is both a southern border and a western border, but not an eastern border, since it has place number 8 as its *immediate eastern border*; a finer grid or an implementation that admits irregularly shaped places might make place number 12 an eastern border by not admitting place number 8 as its immediate eastern neighbor. If there is only one place, it may may be a northern border, a southern border, an eastern border and a western border all at the same time.

In short the primitive operation list contains representations for four binary distinctions, corresponding to whether or not a given place is one of the four kinds of border, and four directions, which are pairwise either inverses or orthogonal, except for borders. The four binary distinctions are used to define the partitions and the four directions are characterized in terms of them in axioms. The first group of axioms depends on whether or not the input place is a southern border, the second group on whether or not it is a northern border, the third on whether or not it is a western border, and the fourth on whether or not it is an eastern border. The first axiom in each group tells us that the direction relevant to the corresponding partition is an inverse of one other direction unless the input is the corresponding kind of border. The other two axioms in each group tell us that the direction relevant to the partition is orthogonal to the two directions of which it is not an inverse, again unless the input place is the appropriate kind of border region.

7.0 The Orientation Structure

Given a formalization of the notion border, such as the one in Figure 6, we not only can legitimately use the operation in Figure 5, which tests one place to see if it is north of another, but also can generalize it to a structure that tests two places for any given orientation. First we define an operation that tests whether a place is a northern, southern, eastern, or western border, as shown in Figure 7. JOIN, again, is an HOS control structure involving sequence, and INCLUDE is an HOS control structure involving independent processing of a number of different operations; along with OR, they constitute the three primitive control structures of HOS, in terms of which any other control structure can be defined. Clone is a universal primitive operation that produces an indicated number of copies of some variable and its value; Or is an operation on data type BOOLEAN that produces an output True if any one of a number of boolean inputs is True, and False, otherwise.

Second we use this border-region operation to define a partition in an orientation structure, as shown in Figure 8. The structure F-orientation enables us to test the orientation of any place p_1 with respect to any place p_2; it is a generalization of the IsNorth operation in Figure 5, obtained by replacing North in Figure 5 with an arbitrary orientation operation F and replacing NBorder in Figure 5 with the more general Border Region operation. Whereas IsNorth in Figure 5 is a specific operation, F_0 in Figure 6 is a variable operation; it is this fact that makes what is defined in Figure 6 a structure rather that an operation.

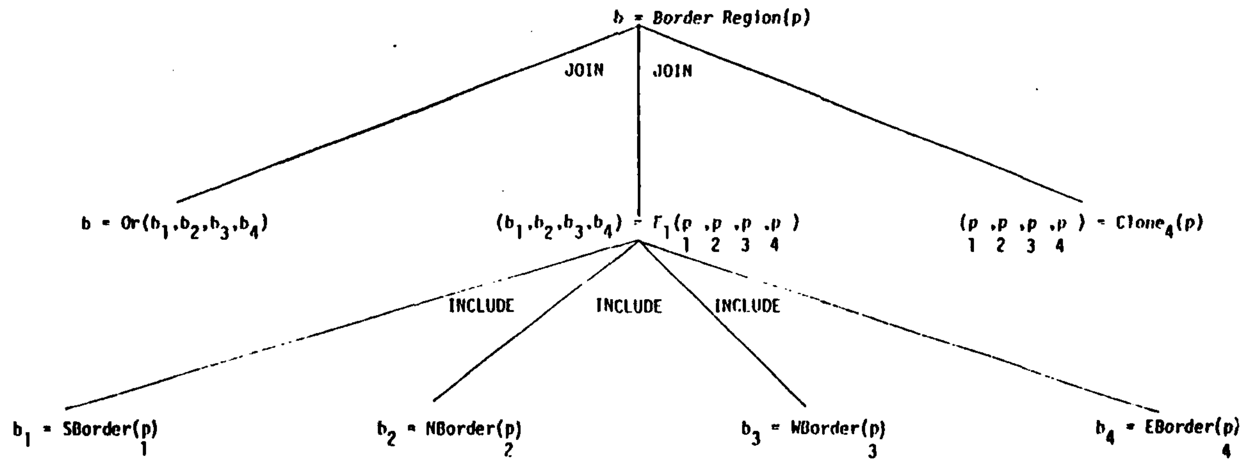
OPERATION: b = Border Region (p);
WHERE b, b_1, b_2, b_3, b_4, ARE BOOLEANS;
WHERE p IS A PLACE;

b = Or(b_1,b_2,b_3,b_4) JOIN (b_1,b_2,b_3,b_4) = F_1(p_1, p_2, p_3, p_4) JOIN (p_1, p_2, p_3, p_4) = $Clone_4$(p);

b_1 = SBorder (p_1) INCLUDE b_2 = NBorder(p_2) INCLUDE b_3 = WBorder (p_3) INCLUDE b_4 = EBorder (p_4);

END Border Region;

(a) AXES Syntax for Operation Border Region: First Approximation

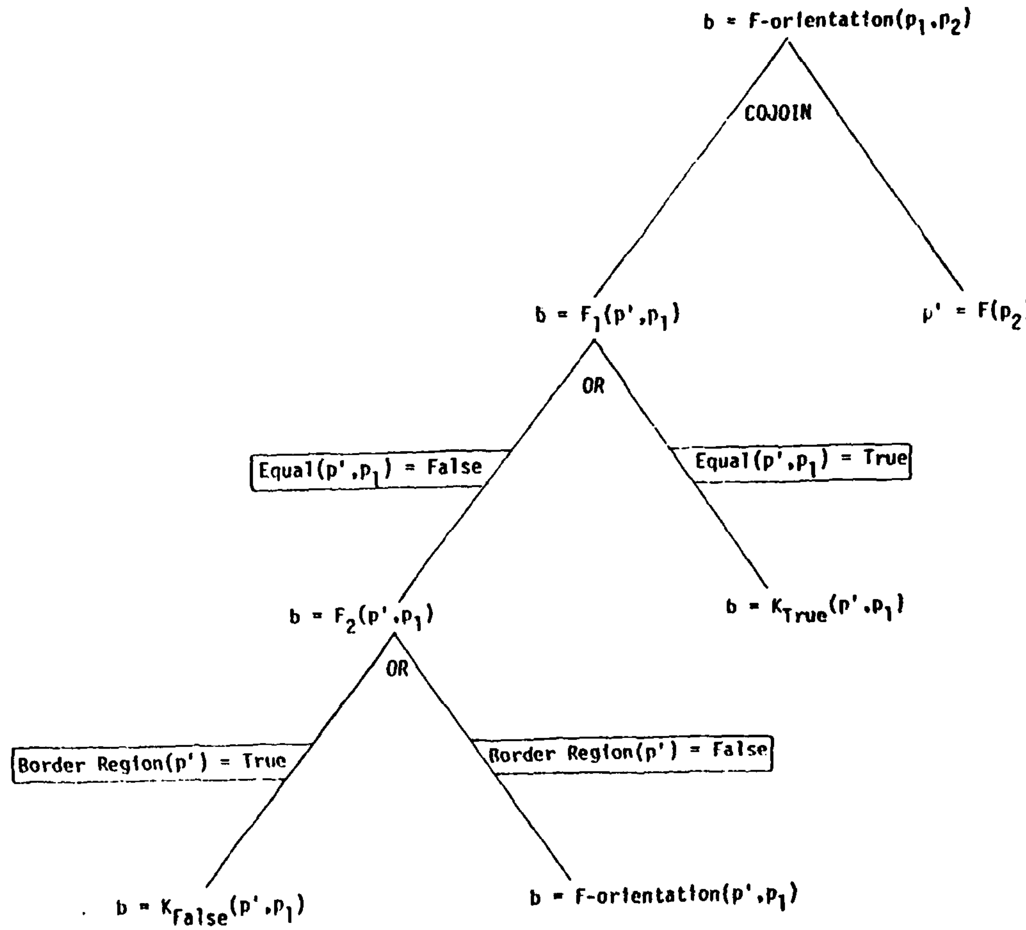


(b) Control Map for Operation Border Region: First Approximation

Fig. 7 Operation That Tests Whether A Place Is A Northern, Southern, Eastern or Western Border: First Approximation

```
STRUCTURE:  b = F-orientation(p1,p2);
   WHERE b IS A BOOLEAN;
   WHERE p1, p2, p' ARE PLACES
b = F1(p',p1) COJOIN p' = F(p2);
b = F2^1(p',p1) OR b = KTrue^2(p',p1);
PARTITION OF (p',p1) IS
   ^1(p',p1)| Equal(p',p1) = False,
   ^2(p',p1)| Equal(p',p1) = True;

b = KFalse ^3(p',p1) OR b = F-orientation ^4(p',p1);
PARTITION OF (p',p1) IS
   ^3(p',p1)| Border Region(p') = True,
   ^4(p',p1)| Border Region(p') = False;

Syntax:  b = p1 is F of p2;

END  F-orientation;
```

(a) AXES Syntax for the Orientation Structure



Syntax: b = p_1 is F of p_2;
F-orientation is the orientation structure
F can be any one of North, South, East, or West, or any combination of these.

(b) Control Map for the Orientation Structure

Fig. 8 Structure That Tests the Directional Orientation of One Place with Respect to Another

Note that F in Figure 6 need not be one of North, South, East or West in order for the structure to make intuitive sense; any finite combination of these primitive operations can be used as a value of F. We can test whether p_1 is north of p_2, in other words, as in Figure 5, but we can also test whether p_1 is south of p_2, whether it is northeast of p_2, whether it is southsouthwest of p_2, whether it is north or southwest of p_2, and so on. All we have to do is replace F in the tree with the appropriate combination of the four direction operations and the instantiated structure will then perform the corresponding test.

8.0 Problems With the Second Approximation: Underdetermination of "Border"

There is still a problem, however, with the formalization of the border notion included in Figure 6, and thus also, by implication with the structure in Figure 8. The four border primitive operations are used in Figure 6 to define the partitions that determine when the various binary compositions of direction operations reject, but there are no further constraints on the border operations themselves. Intuitively, a border place is one which has no immediate neighbor in some direction. While this characteristic of border places is reflected implicitly in the axioms of Figure 6, these axioms are weaker in that they deal only with immediate neighbors of immediate neighbors, rather than with immediate neighbors themselves. The value of North(South(p)), for example, is REJECT if the value of SBorder (p) is true, but we have no further information about when the latter is, in fact, the case. The border operations are underdetermined, in other words, with insufficient information being given in the specification to characterize them adequately.

9.0 HOS Specification of "Place": Final Version

This deficiency is remedied in Figures 9, 10, and 13, as illustrated in Figures 11 and 12. Figure 9 contains our final HOS specification

DATA TYPE: PLACE;
PRIMITIVE OPERATIONS:
$place_2$ = North($place_1$)
$place_2$ = South($place_1$)
$place_2$ = East ($place_1$)
$place_2$ = West ($place_1$)

AXIOMS:
WHERE p IS A PLACE
North (South(p)) = ^1p OR K_{REJECT} (^2p);
East (South(p)) = South(East(^1p)) OR K_{REJECT} (^2p);
West (South(p)) = South(West(^1p)) OR K_{REJECT} (^2p);

PARTITION OF p IS
^1p| Equal (South(p), REJECT) = False,
^2p| Equal (South(p), REJECT) = True;
South(North(p)) = ^3p OR K_{REJECT} (^4p);
East (North(p)) = North(East(^3p)) OR K_{REJECT} (^4p);
West (North(p)) = North(West(^3p)) OR K_{REJECT} (^4p);

PARTITION OF p IS
^3p| Equal (North(p), REJECT) = False,
^4p| Equal (North(p), REJECT) = True;
East (West(p)) = ^5p OR K_{REJECT} (^6p);
North(West(p)) = West(North(^5p) OR K_{REJECT} (^6p);
South(West(p)) = West(South(^5p) OR K_{REJECT} (^6p);

PARTITION OF p IS
^5p| Equal (West(p), REJECT) = False,
^6p| Equal (West(p), REJECT) = True;
West (East(p)) = ^7p OR K_{REJECT} (^8p);
North(East(p)) = East(North(^7p) OR K_{REJECT} (^8p);
South(East(p)) = East(South(^7p) OR K_{REJECT} (^8p);

PARTITION OF p IS
^7p| Equal (East(p), REJECT) = False,
^8p| Equal (East(p), REJECT) = True;

END PLACE;

Fig. 9 HOS Specification of Data Type PLACE of data type PLACE. The axioms in Figure 9 are identical to those in Figure 6; the differences between the two specifications lie in their primitive operation lists and in their partitions. Figure 9, like Figure 3, has only four primitive operations, which correspond to the four cardinal directions; the four border operations have been removed from both the primitive operation list and the partitions, which are now defined directly in terms of the non-existence of an appropriate immediate neighbor. North(South(p)) rejects, according to Figure 9, when South(p) is equal to REJECT, rather than when some unspecified SBorder operation happens to have the value True. Clearly, this is what we mean intuitively by a border place.

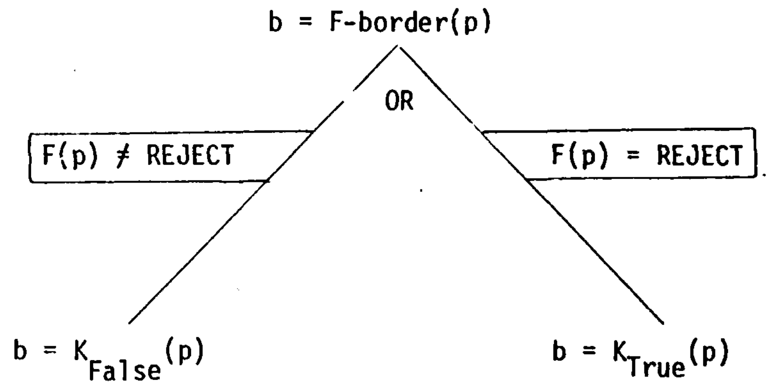
The use of NBorder, SBorder, EBorder, and WBorder as primitive operations in the original partition is peculiar, in other words, because what these operations are is not further specified; these boolean-valued operations are intimately related to the place-valued ones, but this fact is not indicated in the specification (in Figure 6). What is really going on in data type *PLACE is what we see in Figure 9*; the border operations are not primitive at all but consist, rather, in the testing of equality between immediate neighbors and the REJECT element. This recognition enables us to define a border structure that produces an appropriate border operation for each of the four cardinal directions (and combinations thereof). A control map and AXES syntax for this border structure is given in Figure 10.

10.0 The Border Structure

The border structure in Figure 10 is a maximally simple one, consisting of only two levels of decomposition and one control structure, the primitive control structure OR, which provides mutually exclusive and collectively exhaustive alternatives. For a given direction operation F, the structure first partitions the set of places into two disjoint classes, those which have an immediate neighbor in the direction F

```
STRUCTURE:  b = F-border(p);
   WHERE b IS A BOOLEAN
   WHERE p IS A PLACE;
b = K_False(¹p) OR K_True(²p);

PARTITION OF p IS
   ¹p| Equal(F(p), REJECT) = False,
   ²p| Equal(F(p), REJECT) = True;

SYNTAX:  b = (p is a/an F border);
END F-border;
```

(a) AXES Syntax for the Border Structure



Syntax: b = (p is a/an F border)

F-border is the <u>border</u> structure

F can be any function from places to places

(b) Control Map for the Border Structure

Fig. 10 <u>Structure That Tests Whether a Place is a Border Place in Any Direction</u>

(F(p) does not reject) and those which have no immediate neighbor in the direction F (F(p) rejects). If a place p is in the first class, then F-border assigns it a b value of False, indicating that it is not an F border; if p is in the second class, then F-border assigns it a b value of True, indicating that it is an F border.

Note, again, that formulating the border concept as a structure automatically generalizes it beyond the usual N, S, E, W borders we discussed earlier. The function F in Figure 10 can be <u>any</u> mapping at all from places to places. The notion of border makes the most intuitive sense when F is some repeated composition of a single direction operation, and it is probably most useful when F is simply one of N, S, E, and W; the structure also provides, however, for more abstract kinds of borders, which might be useful in some applications, for example, EN borders - - i.e., places which have no neighbor immediately north-east of them - - or WWSS borders - - i.e., places which have no neighbor immediately south-south-west-west of them. Note that the orthographic order of function names is the reverse of that of functional application. We will henceforth use a terminology that reflects the former order to avoid confusion in referring to borders. Some of the possibilities that become available are illustrated in Figure 11.

The examples in Figure 11 deserve careful study. Note that whether or not a place is a boundary place of one sort of another is determined not by the grid, which is included only for intuitive pictorial clarity but by the explicit implementation, in this case given by Figure 4. Place number 46 in Figure 2, for example, looks superficially as if it is not a west-south-south border, because place 53 seems to be its immediate west-south-south neighbor. If we check the table in Figure 4, however, we realize that this is not the case, because place number 2, the immediate southern neighbor of place number 46, itself has no immediate southern neighbor. Looking again at Figure 2, we confirm that this is indeed the case in the picture as well. Place number 46, in other words, is a west-south-south border because South(South(number 46)) rejects and so West(South(South(number 46))) rejects as well. Note

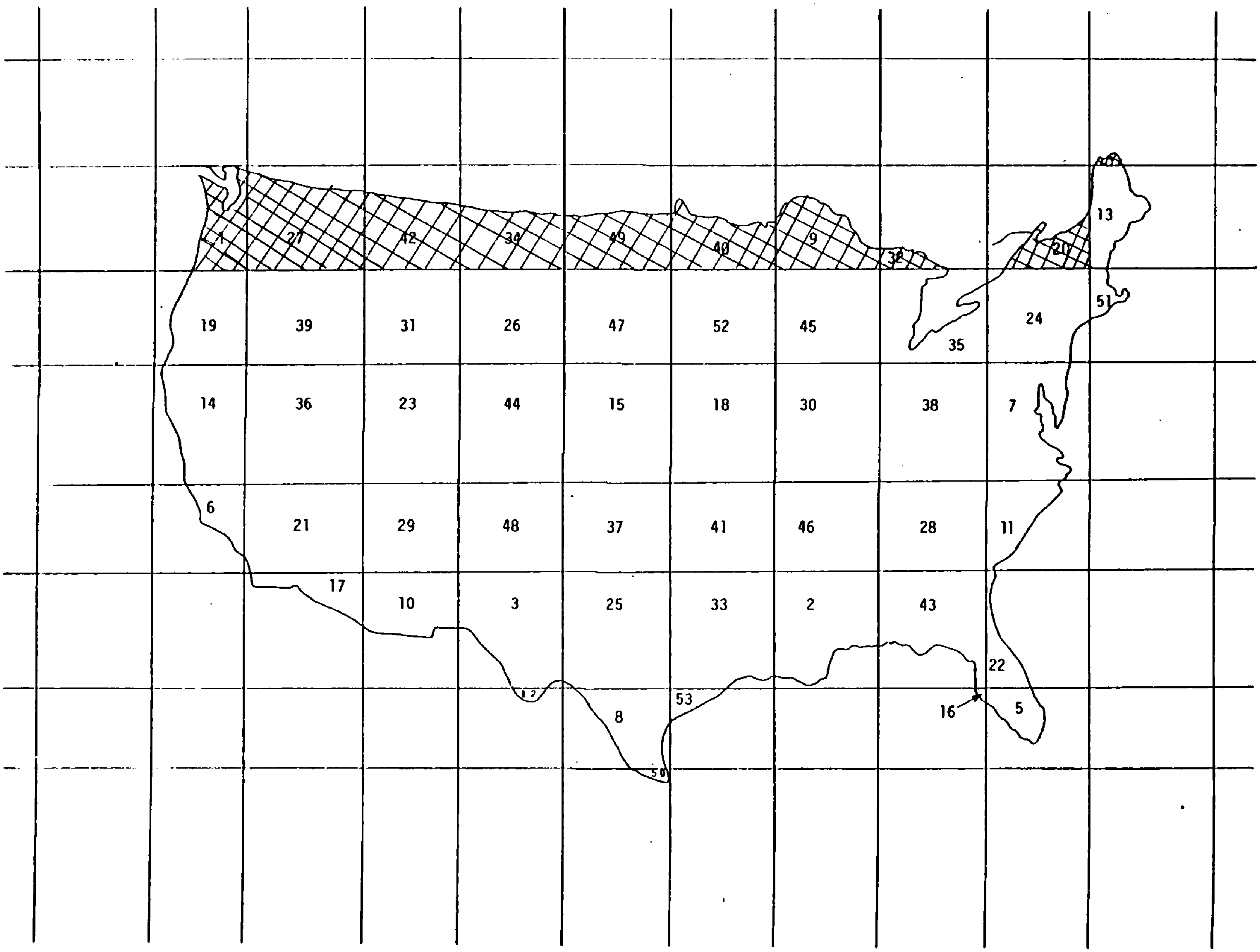


Fig. 11a The North Borders of Figure 2: Places With No Immediate Northern Neighbor

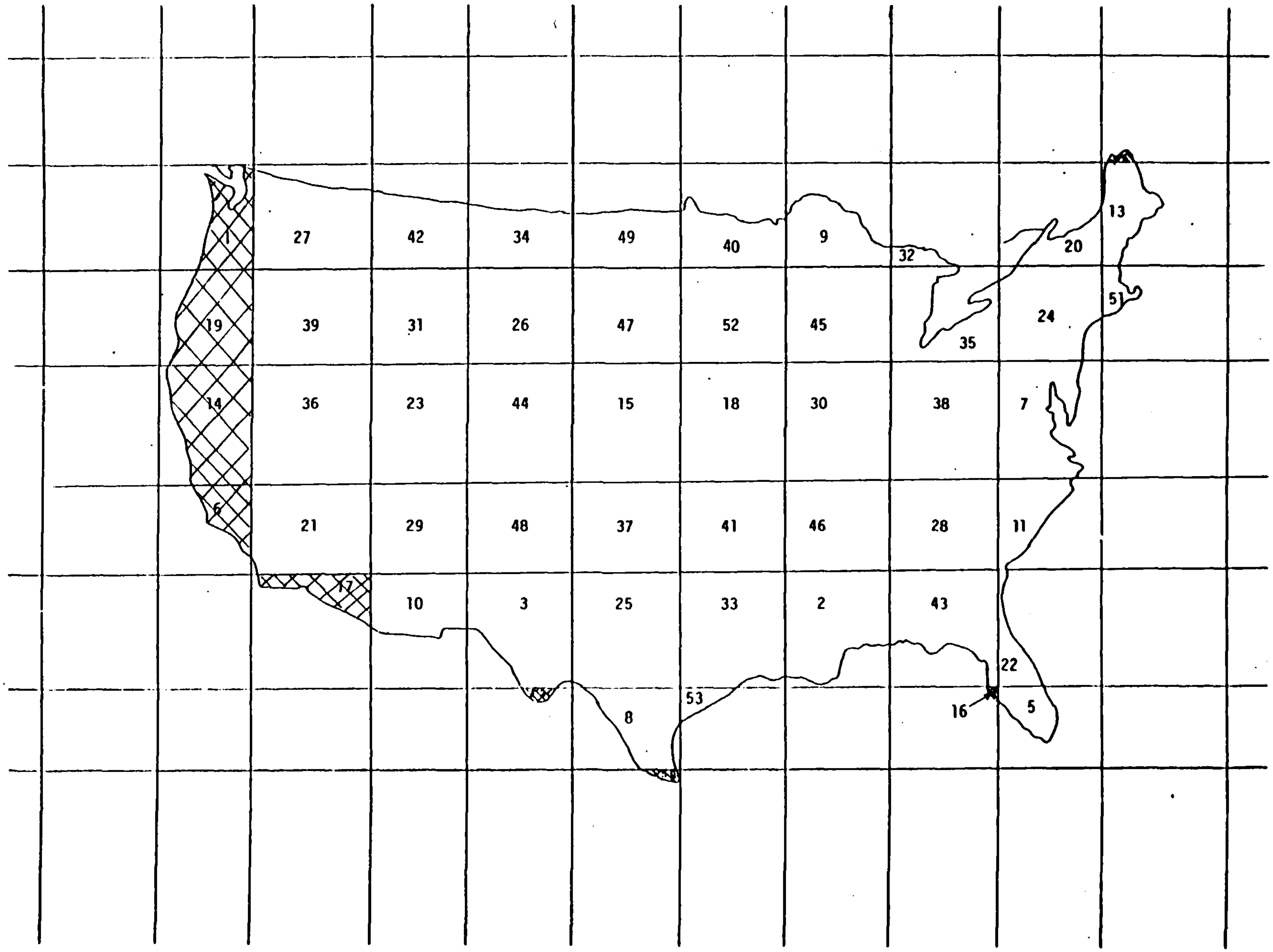


Fig. 11b The West Borders of Figure 2: Places With No Immediate Western Neighbor

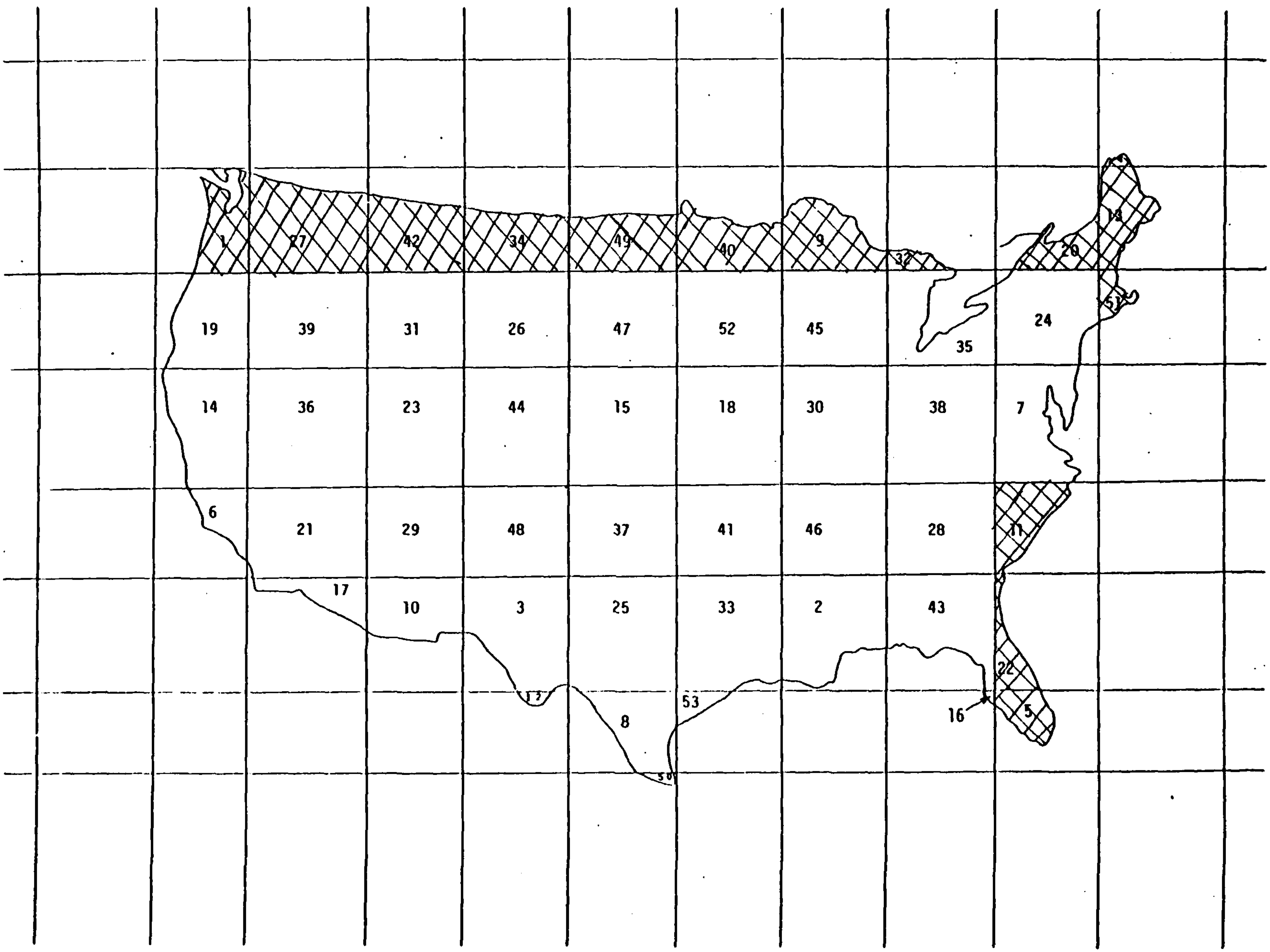


Fig. 11c The East-North Borders of Figure 2: Places With No Immediate East-Northern Neighbor'

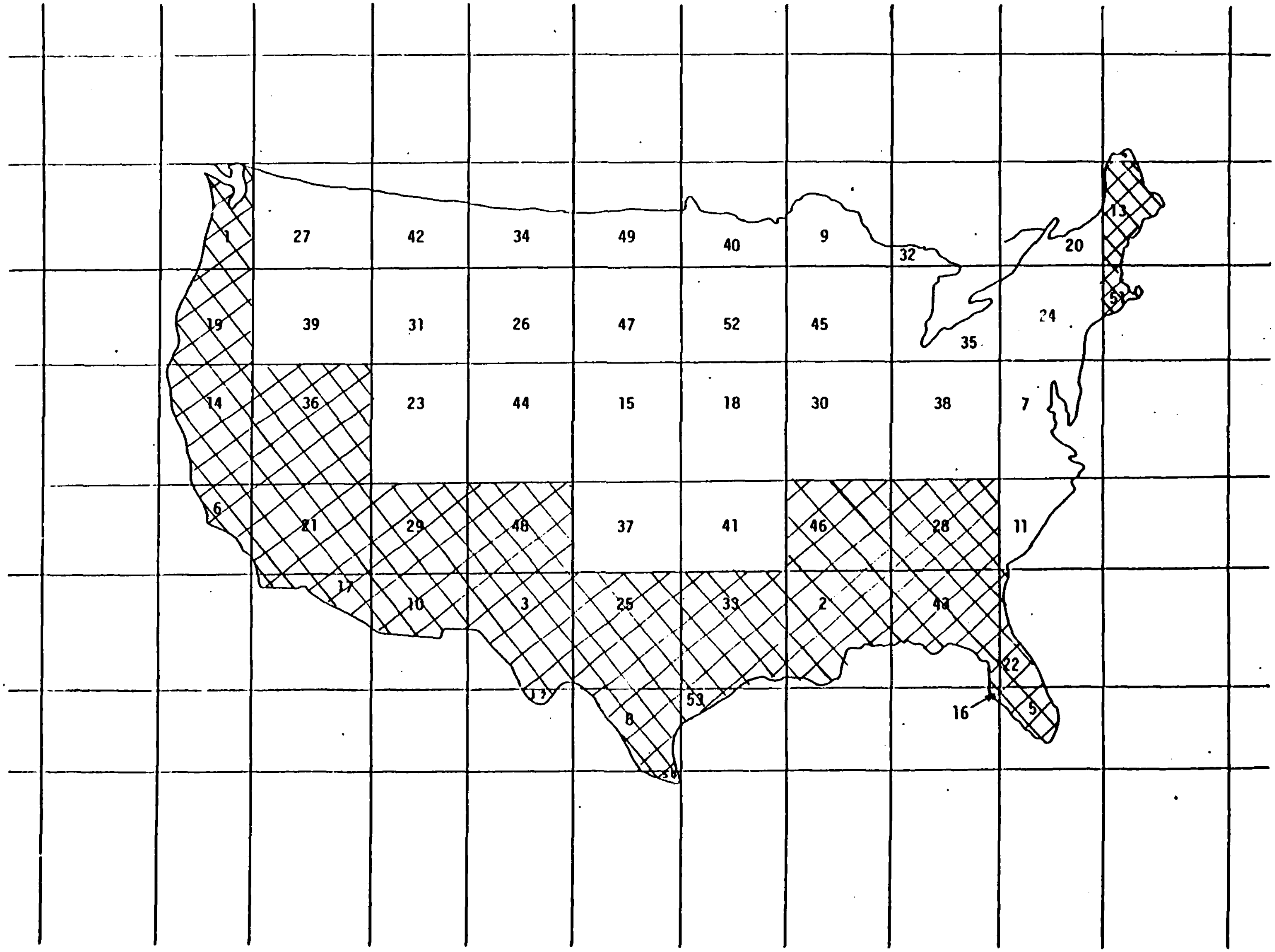


Fig. 11d The West-South-South Borders of Figure 2: Places With No Immediate West-South-Southern Neighbor

also, again using place number 46 as an example, that a West-South-South border is not necessarily a South-South-West border. In this case, West(South(South(number 46))) has value REJECT as we have seen, but South(South(West(number 46))) has place number 53 as its value.

The intuitive character of the border notion can be enhanced by using implementations of Figure 9 based on finer grids that that of Figure 2. In Figure 11d, for example, the eastern coast of Georgia and Maine end up as West-South-South borders, but this does not happen in Figure 12, which uses a finer grid. Conversely, in Figure 11d, most of the land-locked state of Utah and all of Tennessee are counted as West-South-South borders but this does not happen in Figure 12. Note, again, that the sections of a grid do not have to be of uniform size, or even of the same shape, as long as they satisfy the specification in Figure 9. All that matters in the choice of an implementation are the requirements of the problem and the tastes of the user.

11.0 The Border Region Operation

Now that we have fully specified the border notion and adjusted our specification of places accordingly, we can remedy the deficiency that we observed in connection with Figure 8. The problem with Figure 8 was that the operation Border Region, used in the condition of the lowest OR control structure was defined in Figure 7 in terms of SBorder, NBorder, WBorder, and EBorder, which were themselves inadequately characterized in Figure 6 as primitive operations. Having corrected the latter defect, however, by providing the general border structure in Figure 10, we can now use that structure to construct an adequate definition of Border Region.

Our new characterization of Border Region is given in Figure 13. Figure 13 differs from Figure 7 primarily in the way we have just discussed; rather than the symbols "SBorder", "NBorder", "WBorder", and

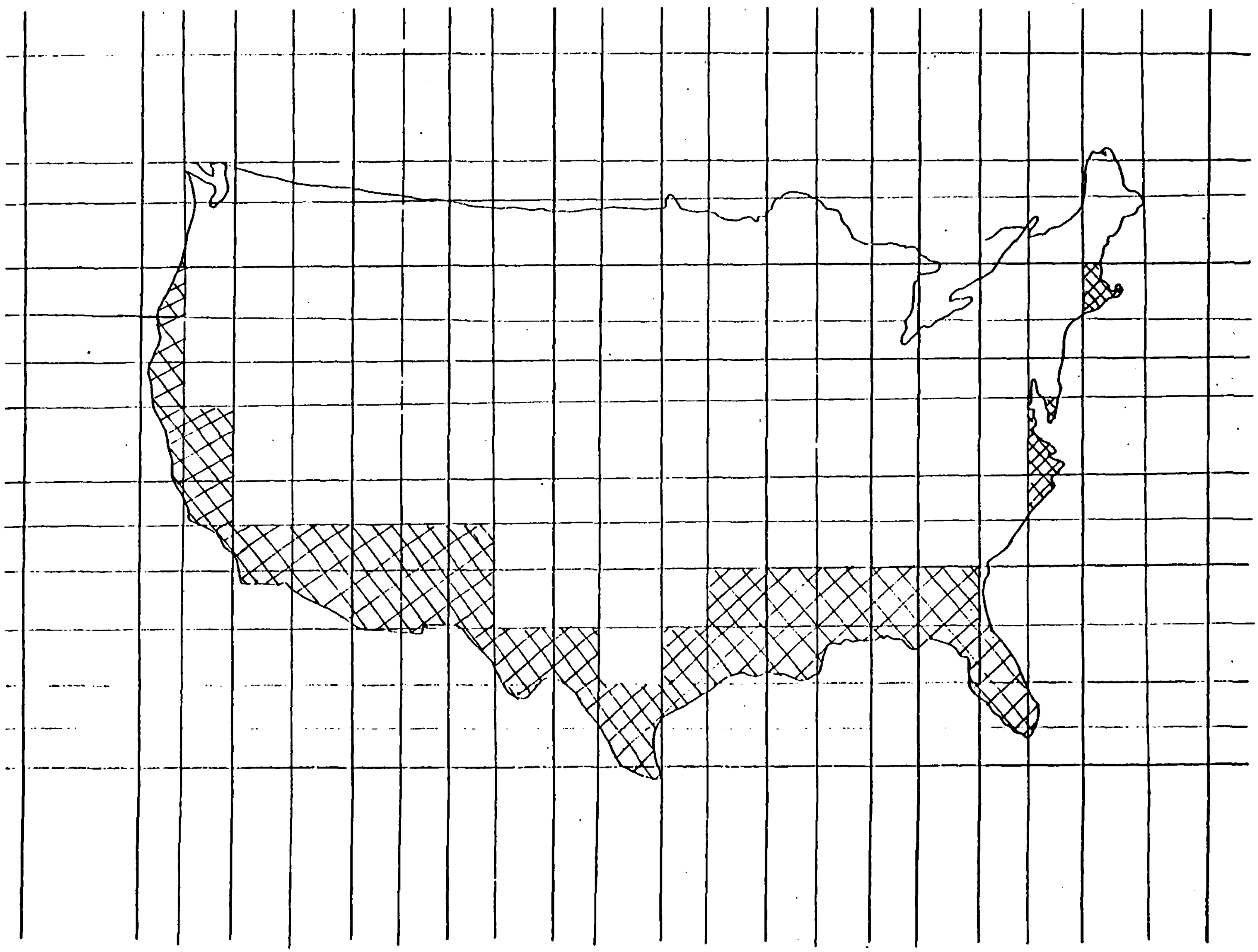
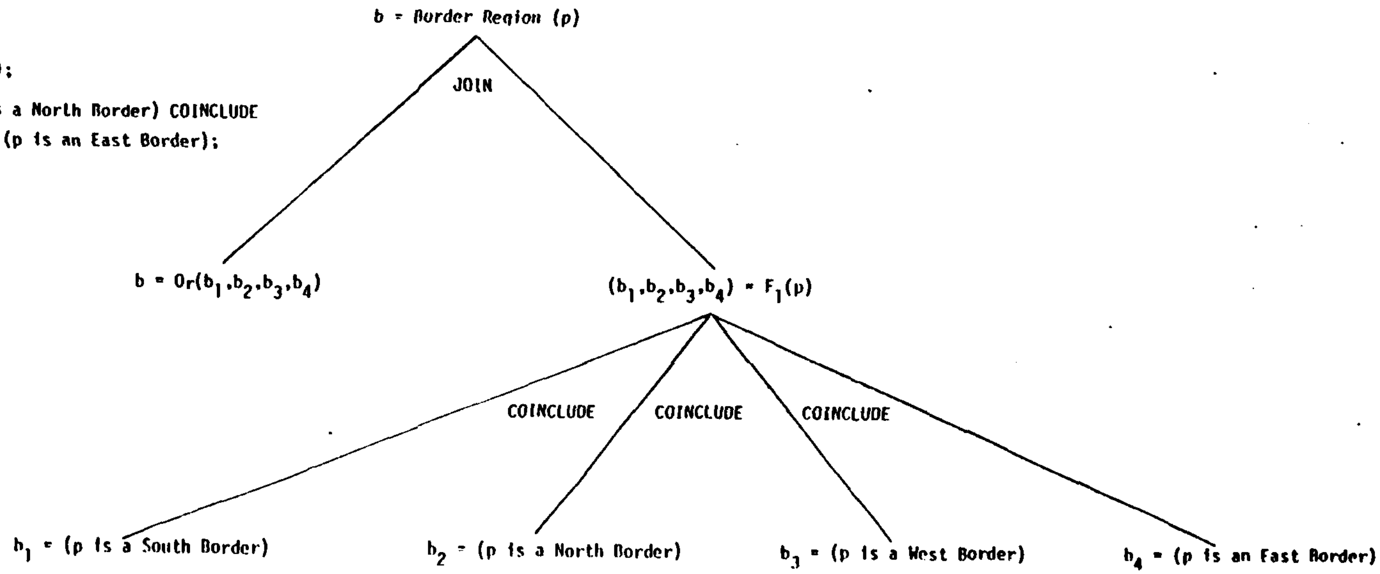


Fig. 12 <u>The West-South-South Borders of an Implementation of Figure 9 With a Finer Grid Than That of Figure 2</u>

```
OPERATION:  b = Border Region (p)
   WHERE b, b1, b2, b3, b4 ARE BOOLEAN;
   WHERE p IS A PLACE;
b = Or (b1,b2,b3,b4) JOIN (b1,b2,b3,b4) = F1(p);
b1 = (p is a South Border) COINCLUDE b2 = (p is a North Border) COINCLUDE
      b3 = (p is a West Border) COINCLUDE b4 = (p is an East Border);
END Border Region;
```

(a) AXES Syntax for Operation Border Region



(b) Control Map for Operation Border Region

Fig. 13 Operation That Tests Whether a Place is a Northern, Southern, Eastern or Western Border

"EBorder", we use the syntax of Figure 10 for four of the operations that structure defines: "p is a South border", "p is a North border", "p is a West border", and "p is an East border". We have also simplified the operation somewhat, by using the non-primitive HOS control structure COINCLUDE, rather than the primitive control structure INCLUDE plus the universal Clone operation. This also enables us to eliminate one of the JOIN control structures that we needed in Figure 7.

12.0 The Coordinates Operation

Now we are in a position to construct what is, perhaps, the most fundamental and important operation on data type PLACE, other than those used in specifying the data type itself. Given two places, it is often essential to know the relative location of one of them with respect to the other. Clearly, if we are given a pictorial implementation of the data type, with two places indicated, the problem is a trivial one, as illustrated in Figure 14. All we have to do is count up or down and right or left from one place to the other and we determine where they are with respect to one another. In Figure 14, we determine immediately that place number 28 is two places south and six places east of place number 39 just by counting down and to the right. The problem is not so simple, however, if we are given our implementation in the form of a table, such as that in Figure 4, since looking at the entries for places like numbers 28 and 39 gives no indication at all as to what their relative locations might be in a pictorial grid. In terms of the specification in Figure 9, furthermore, the problem becomes still more complex, because no specific places such as 39 and 28 are even identified. Since a specification gives only the general properties of the members of a data type, what we really need in connection with our specification of data type PLACE is a definition of what we mean <u>in general</u> by the relative locations of two places. Given a particular implementation of the data type, this definition should then provide an intuitively natural notion of relative place for the places provided by

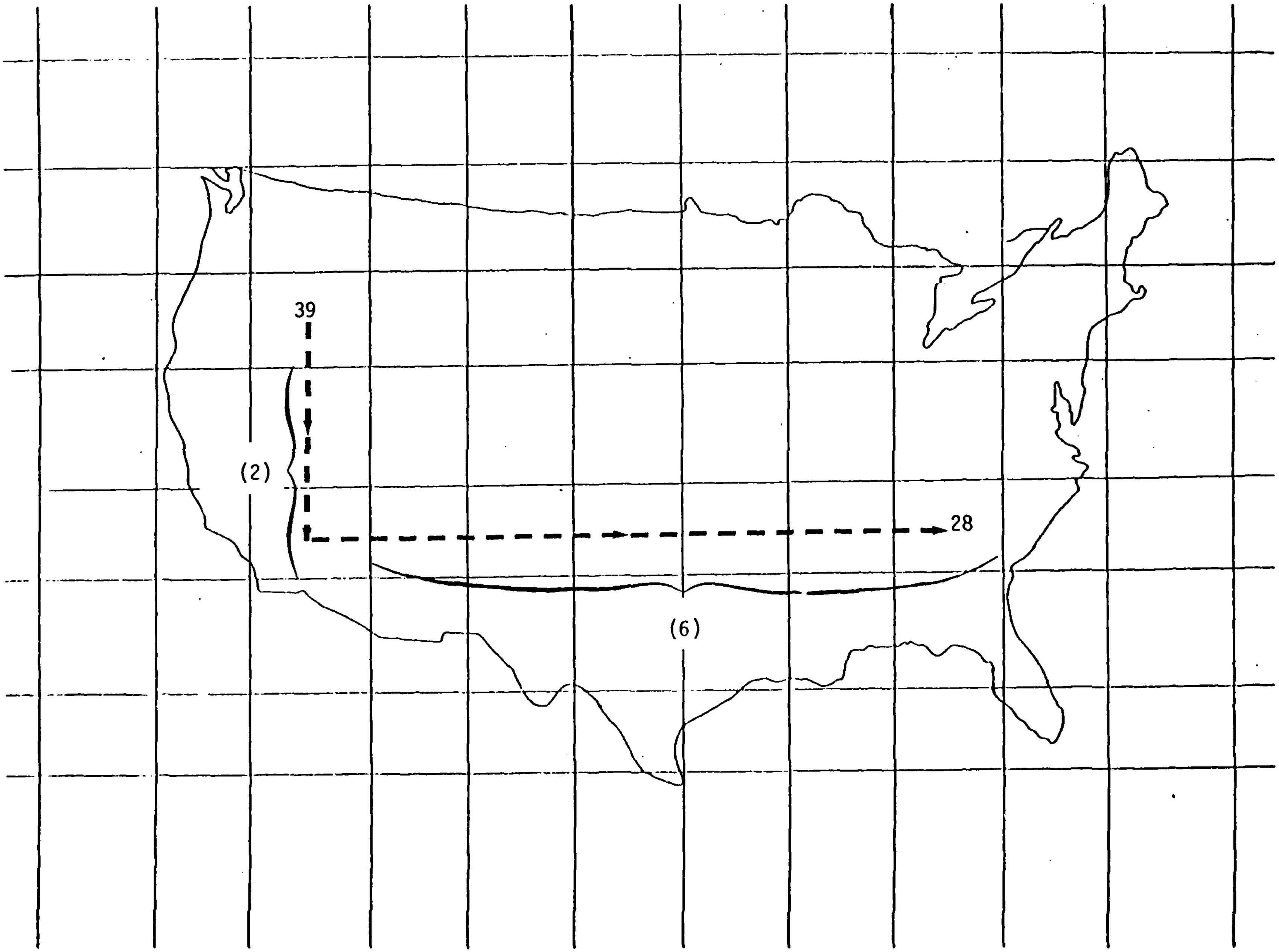


Fig. 14 Given A Pictorial Implementation, The Coordinate Problem is Trivial

that implementation. Such a definition is provided by the operation Coordinates that we will construct here.

The basic idea behind the operation is illustrated in Figure 15, which uses the grid of Figure 12 as a sample implementation. In contrast to the case of Figure 14, in which the relative orientations of the respective places are known and only the coordinates are lacking, the general situation on the specification level lacks even the information about orientation. If we choose two places at random, we do not even know in what direction either lies in with respect to the other, if a pictorial representation is not provided. This deficiency can be overcome by generating search rays in all four cardinal directions from each of the two places, as illustrated in Figure 15. Eventually, one of the rays from each place will intersect one of the rays from the other and the coordinate count can be made from the point of intersection. Actually, two such intersection points will always be generated, but the same coordinates will result by counting from either one.

The control map for the coordinates operation is given and clarified in Figures 16 - 29. Figure 16 gives the top-level architecture of the operation, which consists of Initialize, Test, and Finalize modules. The Initialize module serves only to provide initial values for all of the relevant variables and requires no further explication. Its complete decomposition is given in full in Figure 17. Note that variables in the control map that are of the form $\overline{x}$ are lists, as explained in Figure 18. The test module is the meat of the operation, since it is this module that generates the search rays and determines when an intersection has occurred. The upper-level decomposition of this module is given in Figure 19. It is the Finalize module that performs the coordinate count and assigns values to the coordinate variables. Its top-level decomposition is given in Figure 20.

The search rays are represented by the members of the $\overline{\text{osets}}$ variable, which is generated initially by the Initialize Sets submodule of the

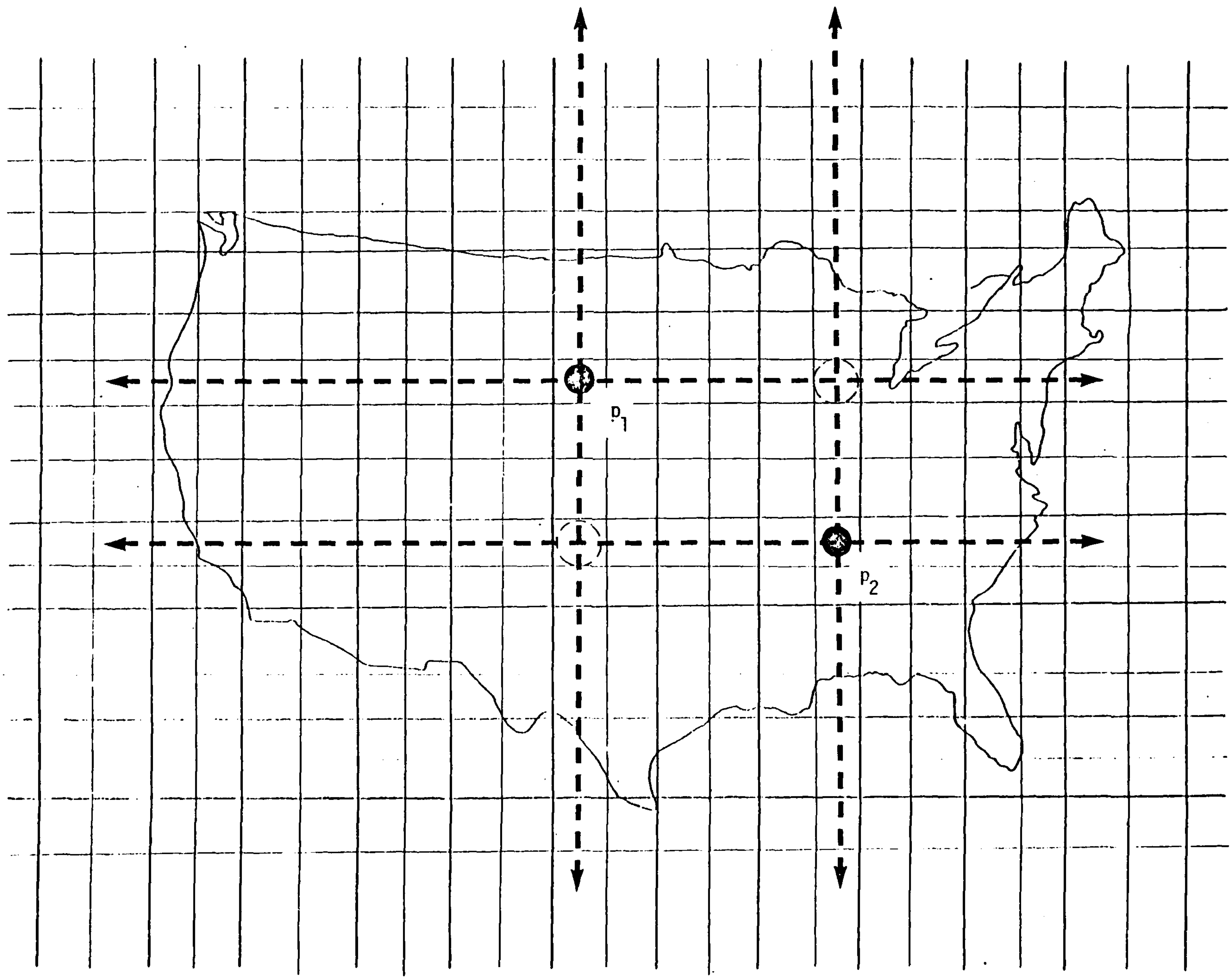


Fig. 15 Determining Relative Orientation as a Preliminary to the Coordinate Count

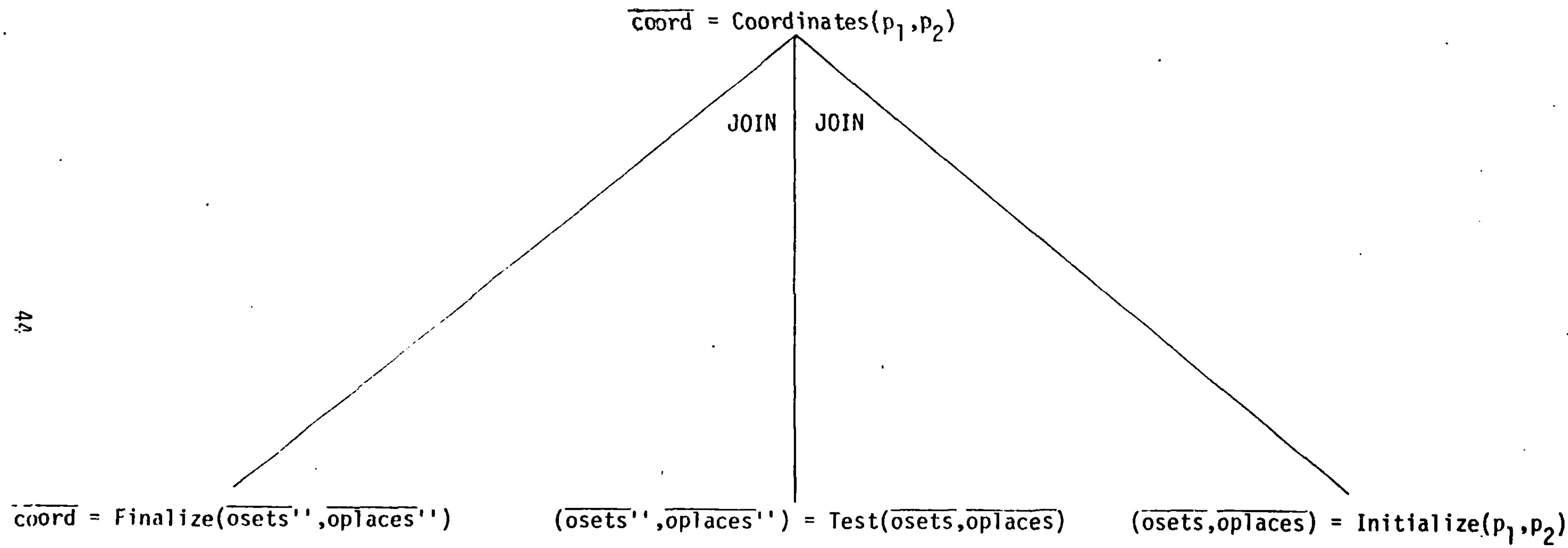


Fig. 16 Top-Level Architecture of Coordinate Operation

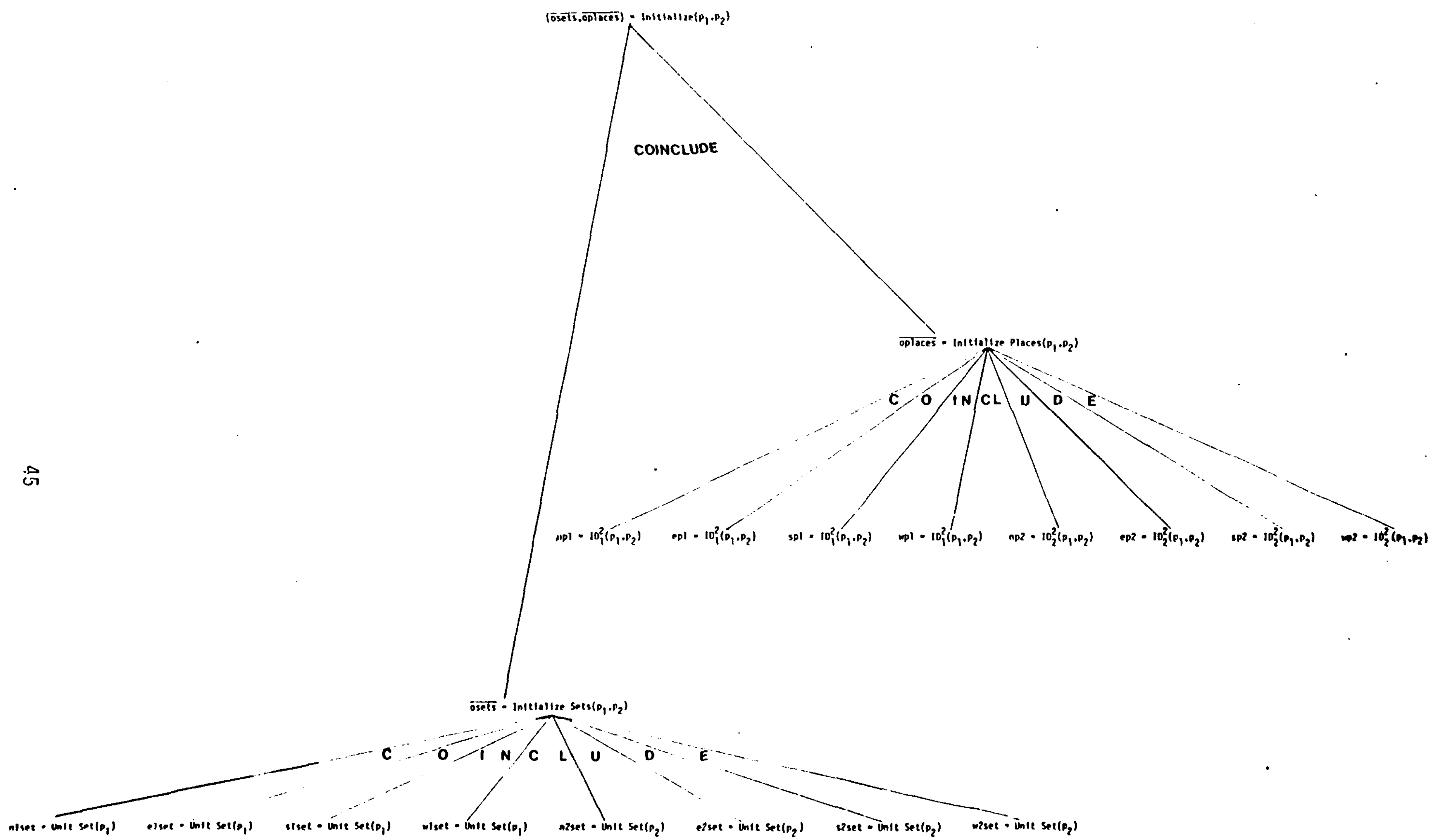


Fig. 17 Initialize Module of the Coordinate Operation

$\overline{\text{coord}}$	(n, e, s, w)	(Coordinates)
$\bar{0}$	(0, 0, 0, 0)	(all zero)
$\overline{\text{osets}}$	(n1set, e1set, s1set, w1set, n2set, e2set, s2set, w2set)	(Orientation Sets)
$\overline{\text{oplaces}}$	(np1, ep1, sp1, wp1, np2, ep2, sp2, wp2)	(Orientation Places)
$\overline{\text{obooleans}}$	(n1e2, n1w2, e1n2, e1s2, s1e2, s1w2, w1n2, w1s2, nse1, n2w1, e2n1, e2s1, s1e2, s1w2, w1n2, w1s2)	(Orientation Booleans)
$\overline{\text{False}}$	(False,False,False,False,False,False,False,False,False,False,False,False,False,False,False,False)	(all false)
$\overline{\text{input}}$	($\overline{\text{obooleans}}$, $\overline{\text{osets}}$, $\overline{\text{oplaces}}$)	(input to the Assign Coordinates submodule of the Finalize module)

Fig. 18 Abbreviations Used in Control Map of the Coordinate Operation

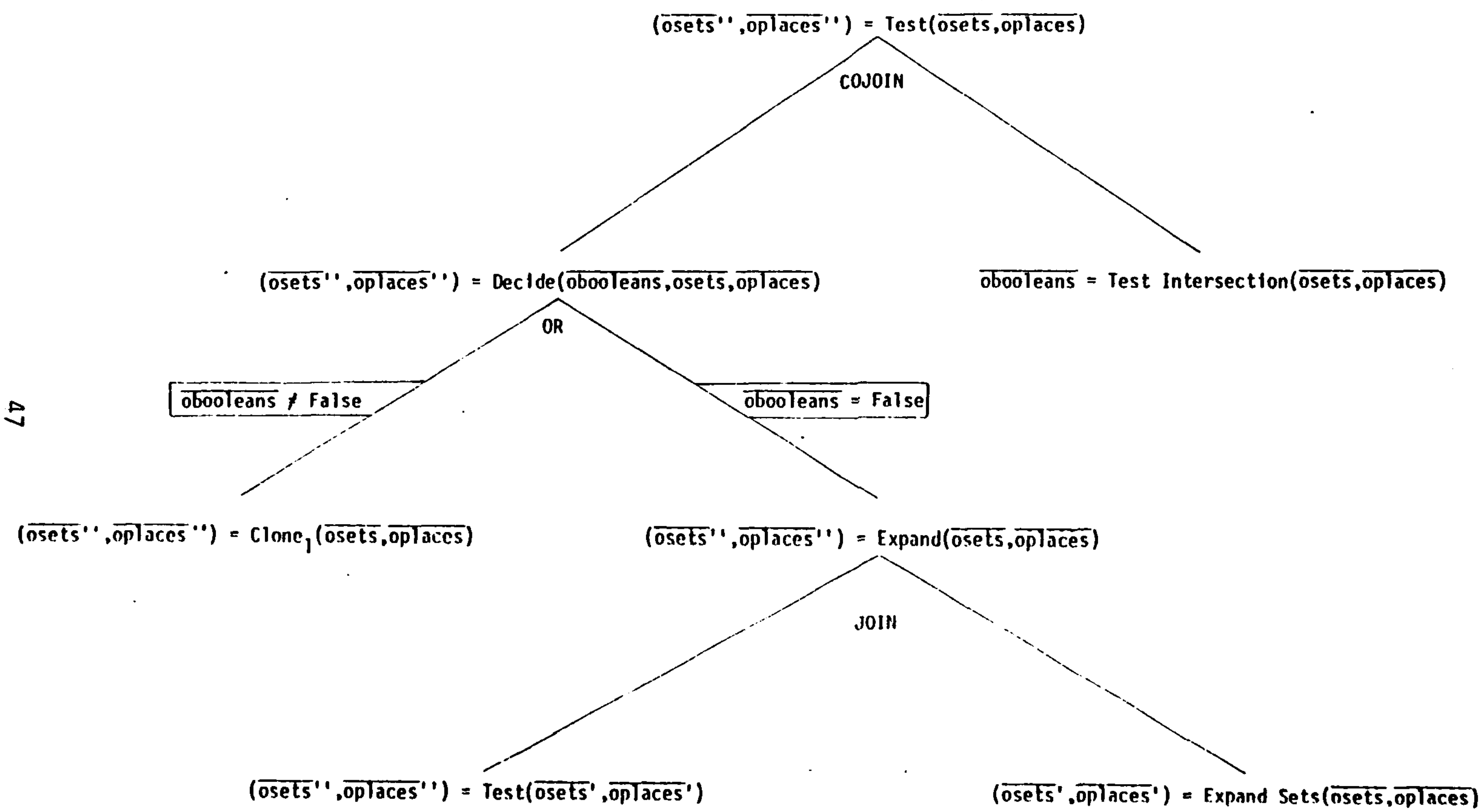


Fig. 19 Test Module of Coordinate Operation

$\overline{\text{coord}} = \text{Finalize}(\overline{\text{osets}}'', \overline{\text{oplaces}}'')$

COJOIN

$\overline{\text{coord}} = \text{Assign Coordinates}(\overline{\text{obooleans}}'', \overline{\text{osets}}'', \overline{\text{oplaces}}'')$

$\overline{\text{obooleans}}'' = \text{Test-Intersection}(\overline{\text{osets}}'', \overline{\text{oplaces}}'')$

Fig. 20 Finalize Module of Coordinate Operation

Initialize module and expanded later by the Expand Sets submodule of the Test module. Expand Sets, shown in Figure 21, takes the sets of places in each direction from a given place and adds the next place in each direction to the respective set, using the Expansion Structure given in Figure 22. An HOS specification of data type FINITE SET is given in Figure 23, with the Unit Set operation of Figure 17 given in Figure 24. Note that, according to this specification, a FINITE SET can be implemented as any finite set-like object: stacks, queues, files, and so on, given that a cardinality operation is defined on them. Building a FINITE SET (OF T) for some type T is like marking the members of T with a label. This is, in effect, the way finite sets are used in the coordinates operation.

The Test Intersection submodule, shown in Figure 25, tests to see whether an intersection has occured between any of the generated search rays. If not, then Expand Sets expands each ray by one place and calls Test again to repeat the whole procedure. If an intersection has occured, then Test is completed and control is passed to Finalize (Figure 20) for the actual determination of coordinate values.

Finalize begins with a recall of Test Intersection, solely in order to regenerate the correct obooleans values needed in Assign Coordinates and then passes control directly to the latter submodule given in Figure 26. It is Assign Coordinates that generates the values for the output variables of the overall Coordinates function. Note that only one of the alternatives contained in Assign Coordinates gets used in any single performance pass, the choice being determined by which search rays happen to intersect on that pass. Each Assign operation of Assign Coordinates differs slightly from the others, as shown in Figure 27, but all make use of the Count structure given in Figure 28. Once the intersection point has been found (Test, Figure 19), it is Count that counts back from that point to one of the input places to determine values for the coordinate variables that represent their relative locations.

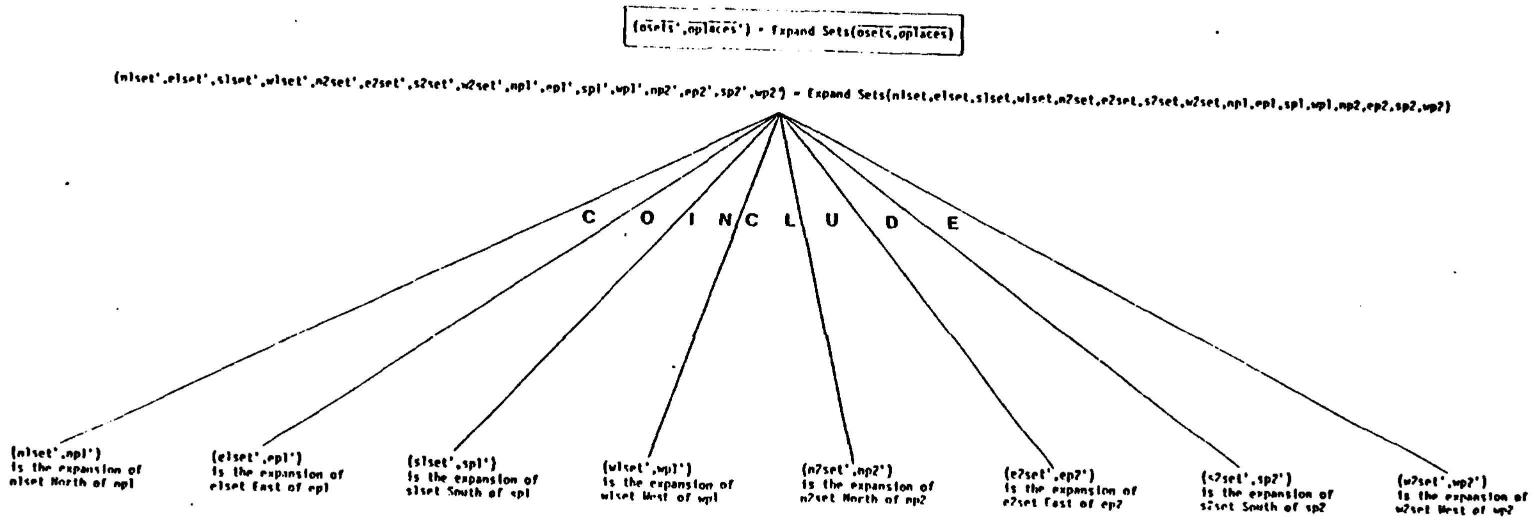
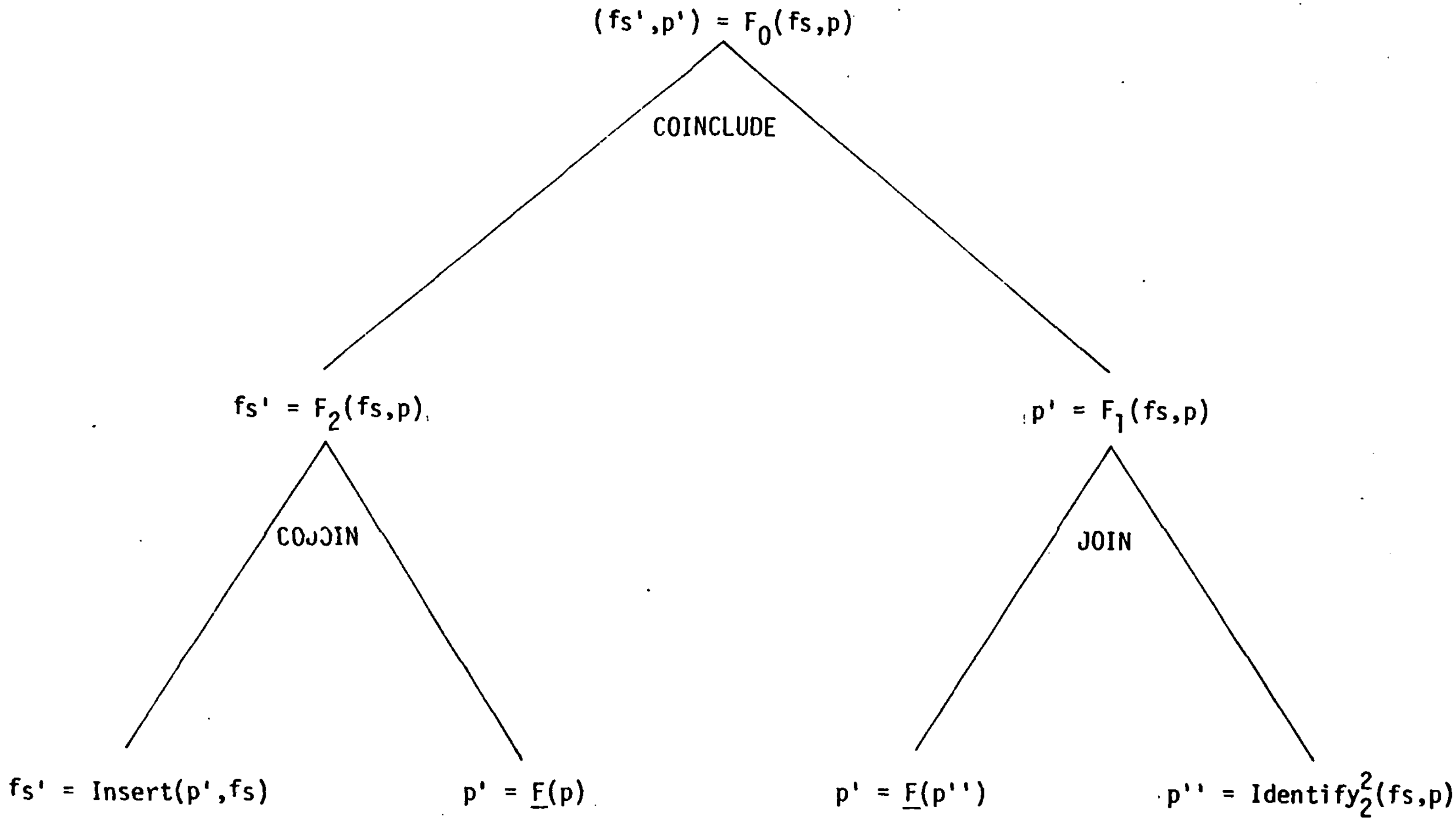


Fig. 21 Expand Sets Submodule of the Test Module



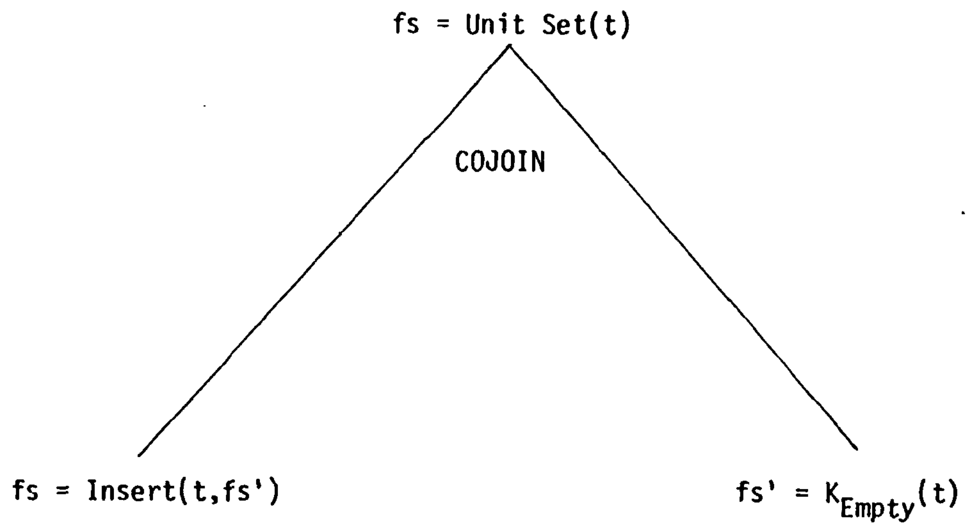
WHERE fs, fs' ARE FINITE SETS
WHERE p,p',p'' ARE PLACES
WHERE F IS AN ORIENTATION OPERATION (Any finite composition of North, East, South, West

Syntax: (fs',p') is the expansion of fs F of p.

Fig. 22 Expansion Structure for the Expand Sets Submodule

```
DATA TYPE:  FINITE SET (OF T);

PRIMITIVE OPERATIONS:

finite set2 = Insert(t, finite set1);
finite set2 = Extract(t, finite set1);
natural = Card(finite set);
boolean = IsIn(t,finite set);

AXIOMS:
   WHERE Empty IS A CONSTANT FINITE SET;
   WHERE t IS A T;
   WHERE fs IS A FINITE SET;

IsIn(t,Empty) = False;
Equal(Extract(t,fs), REJECT) = Equal(IsIn(t,fs), False);

Extract(t, Insert(t,fs)) = fs

Insert (t, Extract (t,fs)) = 1fs OR K_REJECT (2fs);

Card(Empty) = Zero;

Card(Insert(t,fs)) = Succ(Card(fs));

Succ(Card(Extract(t,fs))) = Card(1fs) OR K_REJECT (2fs);

PARTITION OF fs IS
   1fs| Extract(t,fs) ≠ REJECT
   2fs| Extract(t,fs) = REJECT

END FINITE SET;
```

Fig. 23 HOS Specification of Data Type FINITE SET




```
OPERATION:  fs = Unit Set(t)
   WHERE fs, fs' ARE FINITE SETS (OF T);
   WHERE t IS A T;
fs = Insert(t,fs') COJOIN fs' = K_Empty(t);
END UNIT SET;
```

Fig. 24 <u>The Unit Set Operation Used In Figure 17</u>

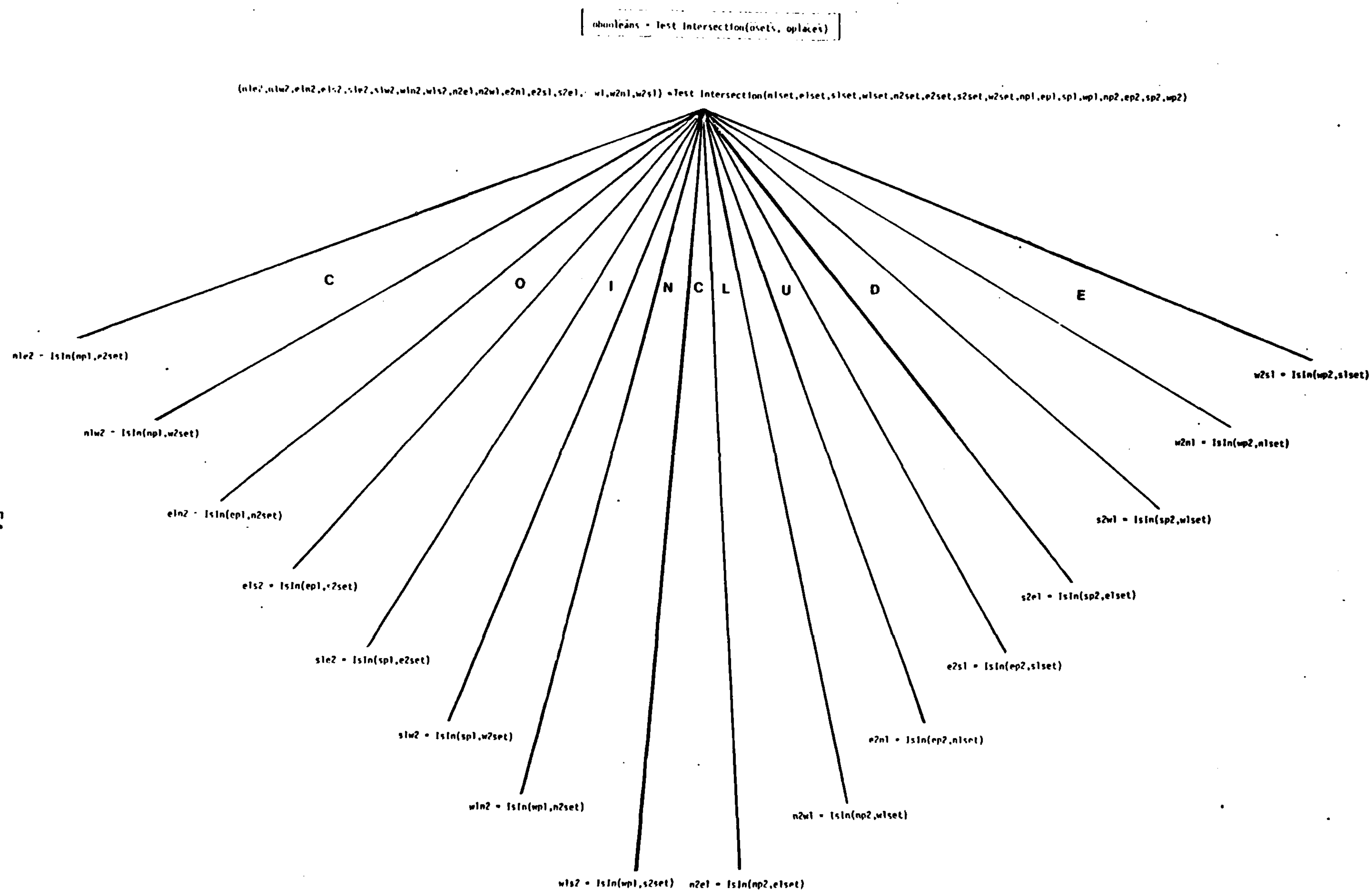


Fig. 25 Test Intersection Submodule of the Test Module

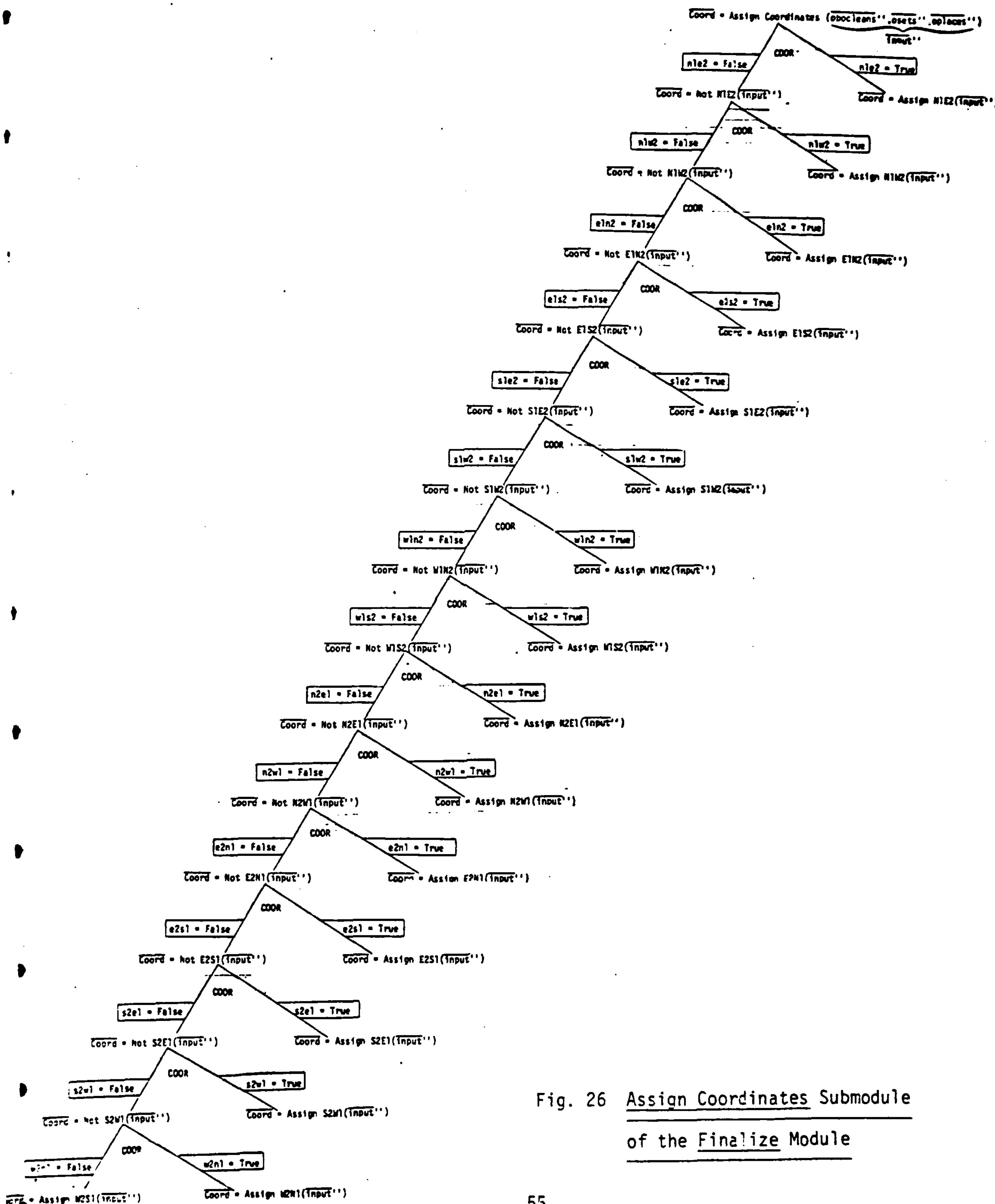


Fig. 26 Assign Coordinates Submodule of the Finalize Module

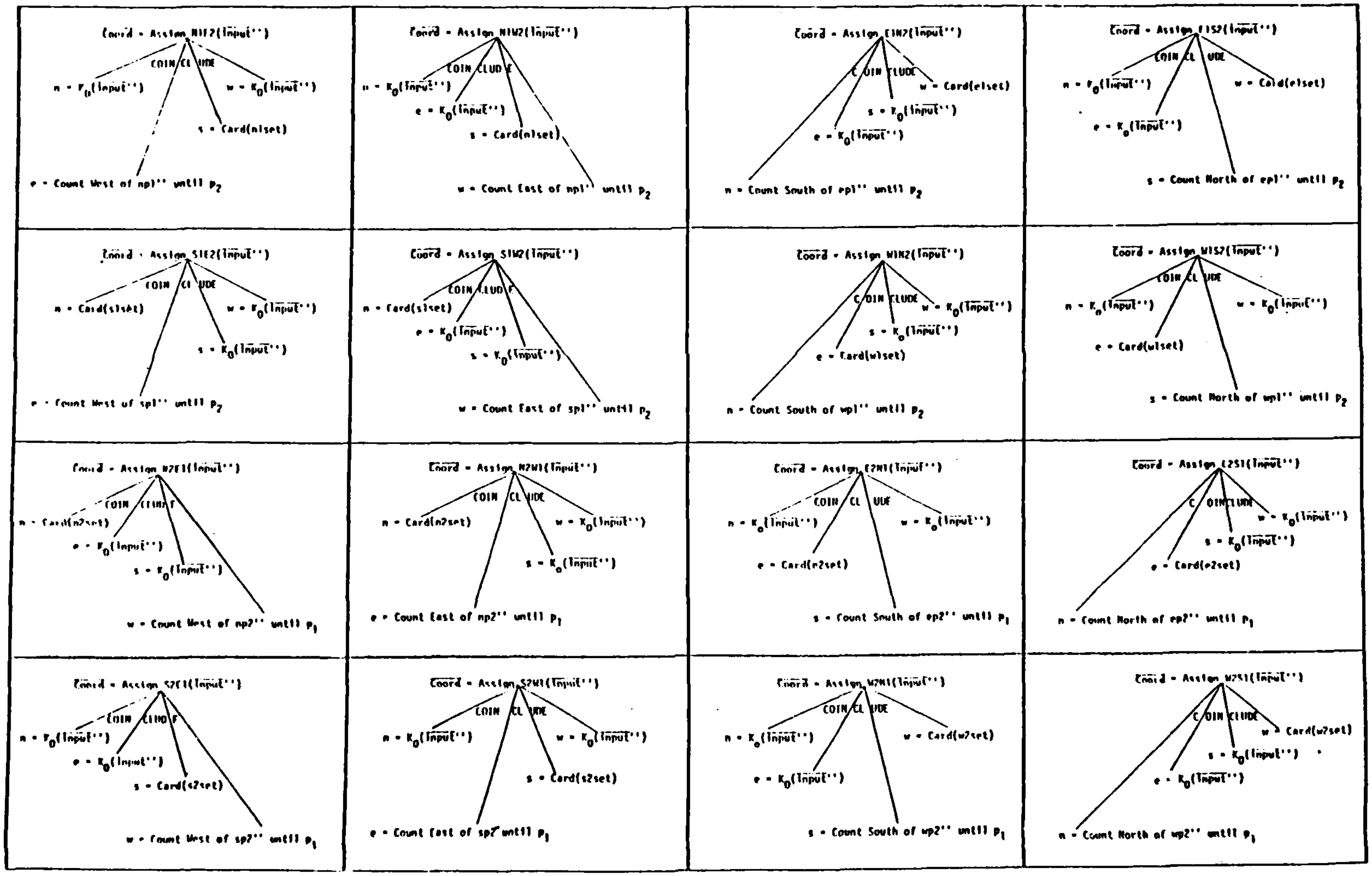
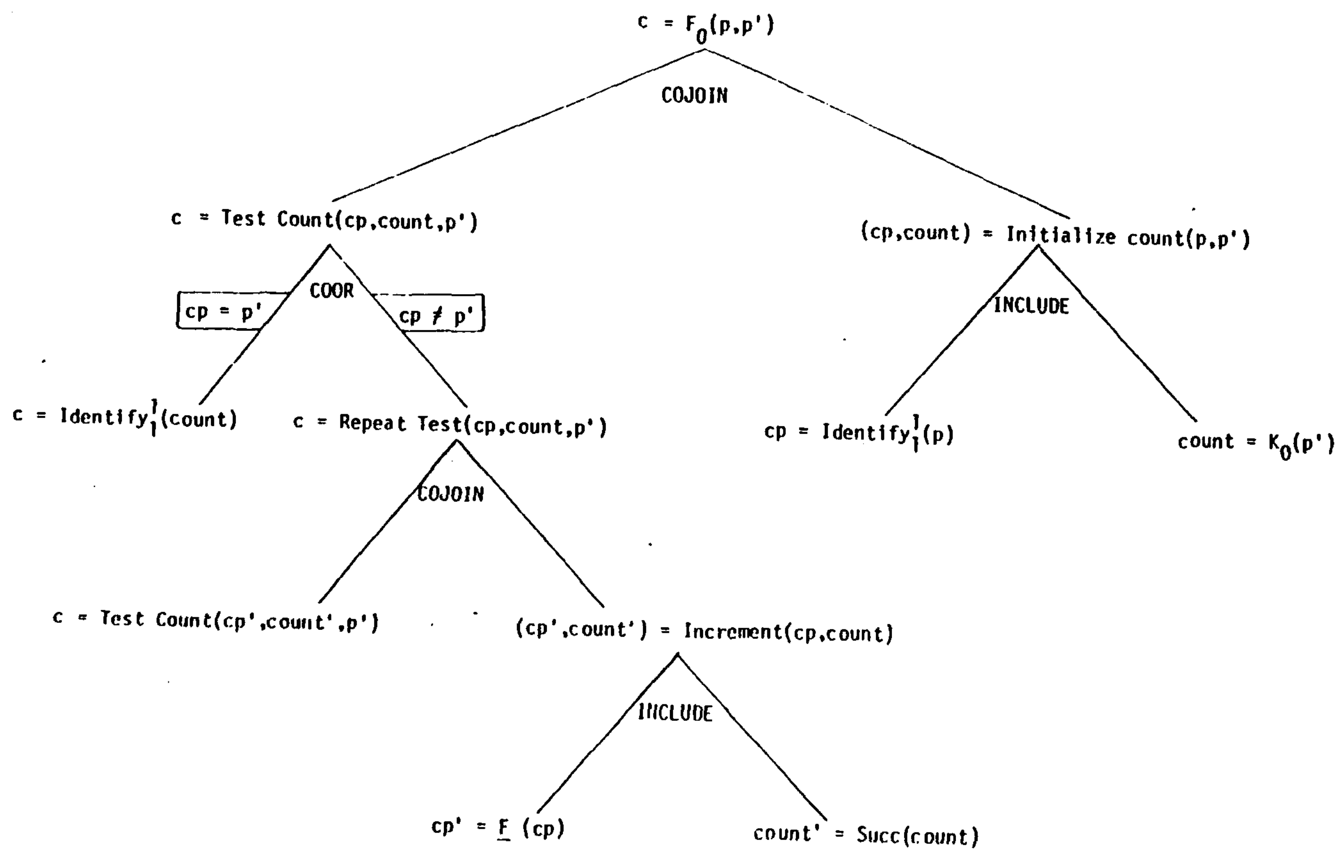


Fig. 27 Assign Operations for Assign Coordinates Submodule



Syntax: c = Count F of p until p' ;

WHERE p,p',cp,cp' ARE PLACES;

WHERE c, count, count' ARE NATURALS;

WHERE F IS AN ORIENTATION OPERATION;
(any finite combination of North, East, South, West)

Fig. 28 <u>Count</u> Structure for the <u>Assign</u> Operations of the <u>Assign</u> <u>Coordinates</u> Submodule

The way the Assign operations work is further elaborated in Figures 29 and 30. Figure 29 contains all possible ways in which the search rays generated from two input places can intersect. For example, n1w2 represents the case in which the ray generated north of p_1 intersects the ray generated west of p_2, while e2s1 represents the case in which the ray generated east of p_2 intersects the ray generated south of p_1. Figure 30 gives, in effect, the coordinate values in each case, of which two are always zero, one is simply the size of the intersecting search ray, and the last is obtained from Count. Note that the diagram in Figure 26 could be simplified somewhat via symmetry considerations, since there are two coordinate-equivalent intersection points for any two input places. Since xnym represents the same relative-location configuration as ymxn in Figure 29, it also yields the same coordinates when the evaluations in Figure 30 are carried out.

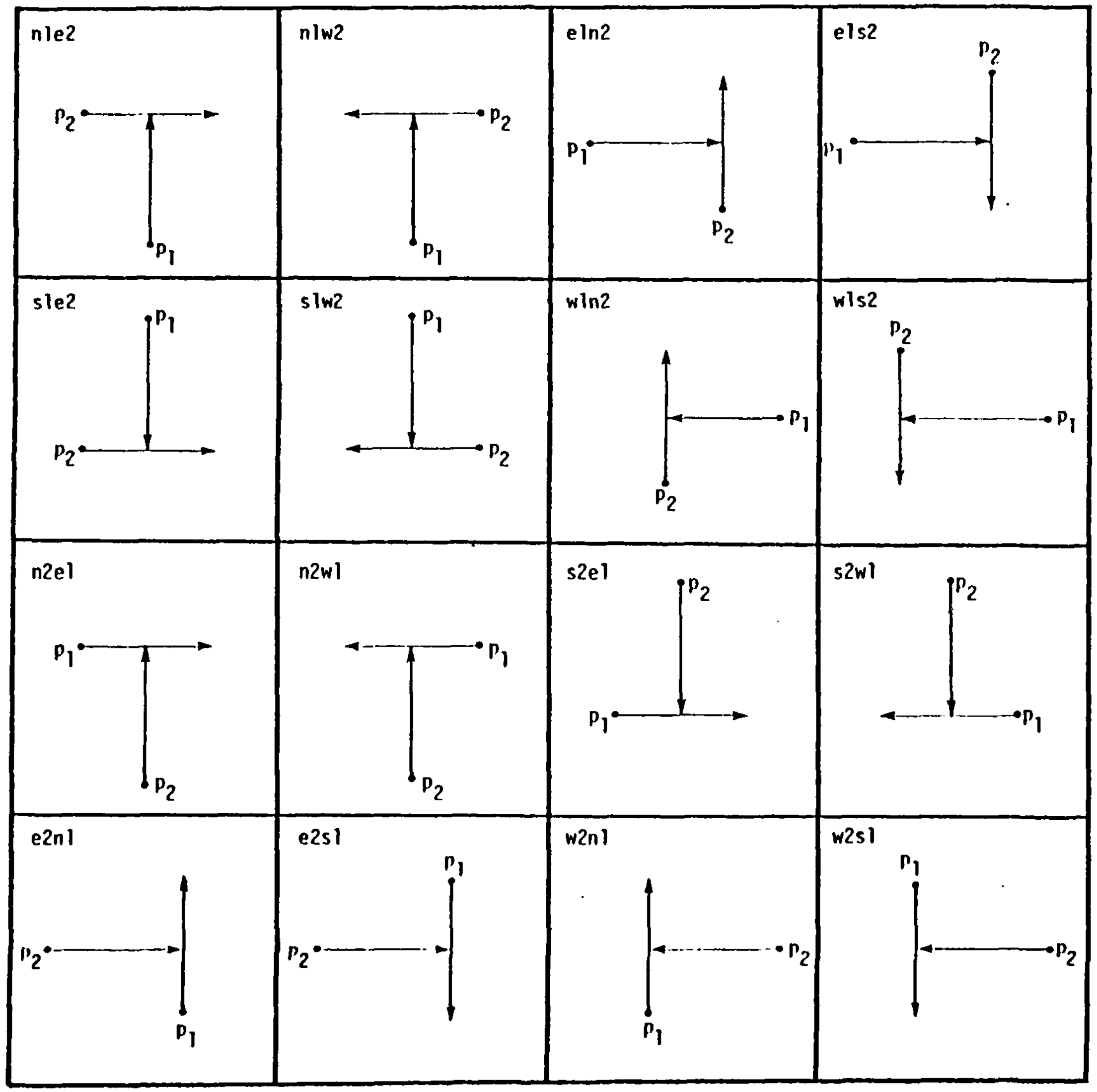


Fig. 29 <u>The Possible Cases of Intersection</u>

	n	e	s	w
n1e2	0	Count West until p_2	Card(n1set)	0
n1w2	0	0	Card(n1set)	Count East until p_2
e1n2	Count South until p_2	0	0	Card(e1set)
e1s2	0	0	Count North until p_2	Card(e1set)
s1e2	Card(s1set)	Count West until p_2	0	0
s1w2	Card(s1set)	0	0	Count East until p_2
w1n2	Count South until p_2	Card(w1set)	0	0
w1s2	0	Card(w1set)	Count North until p_2	0
n2e1	Card(n2set)	0	0	Count West until p_1
n2w1	Card(n2set)	Count East until p_1	0	0
e2n1	0	Card(e2set)	Count South until p_1	0
e2s1	Count North until p_1	Card(e2set)	0	0
s2e1	0	0	Card(s2set)	Count West until p_1
s2w1	0	Count East until p_1	Card(s2set)	0
w2n1	0	0	Count South until p_1	Card(w2set)
w2s1	Count North until p_1	0	0	Card(w2set)

Fig. 30 The Coordinate Values in Each Case of Intersection

SECTION IV

AN INTEGRATED DESIGN FOR INDUSTRIAL RELOCATION AND RECEPTION/CARE PLANNING SYSTEMS

"Industrial Relocation Planning" and "Reception and Care Planning" are two large subsystems of civil defense. In "On Industrial Relocation" a design of an industrial relocation system was presented. This effort examines "Reception and Care Planning" using the HOS methodology, and, then, provides a new design for the system of Reception and Care Planning. Furthermore, using HOS, Industrial Relocation Planning and Reception and Care Planning are integrated into a unified subsystem. This is the first attempt at an integrated design of any subsystems of civil defense.

"On Industrial Relocation" provided an explicit design via an HOS control map of a relocation system that satisfied various requirements. From this design an induced set of requirements were obtained which certainly aids civil defense planners. To review briefly, the original list of requirements were:

1. to save the labor force of key organizations,
2. to develop a host area plan(HAP),
3. to develop a risk area plan (RAP),
4. to provide various support,
5. to schedule movement.

The control map allowed us to extend this list to:

6. that the host area plan and the risk area plan cannot be developed concurrently, in fact, the host area plan must be developed before the risk area plan,
7. providing support is part of the risk area planning as well as the host area planning, i.e., submodule of the modules risk and host area planning,
8. scheduling movement is a submodule of risk area planning,
9. scheduling must be dependent on other organizations and also should take into consideration spontaneous or undirected evacuation of part of the population at large.

Moreover, in constructing the control map some of the problems of the system became apparent. These are:

1. lack of explicitness in describing what the functions of the system are,
2. lack of explicitness in describing the inputs and outputs of the various functions,
3. abundance of pseudomodules,
4. lack of interorganizational planning.

The ability to isolate precise problems is vital to civil defense planners. Details of this system can be found in "On Industrial Relocation."

The design of the reception/care plan is based on the "system" found in Reception and Care Planning Guidance For Host Communities, especially "Volume II: Planning Steps and Instructions." The basic idea of this plan can be summed up in the 7 steps [1].

1. The description and listing of individual host area buildings which can be used as congregate lodging facilities by evacuees - including the congregate lodging capacity of each structure.

2. The designation of fallout shelter and feeding facilities which can be used by evacuees lodged in each building in 1 above.

3. The distribution of the maximum number of evacuees across the above designated lodging, shelter, and feeding facilities.

4. The designation of special care facilities which will be used by special groups of evacuees posing special needs or problems.

5. The division of the host jurisdiction into R/C districts and component Lodging Sections, whose headquarters will supervise a manageable number of evacuees and the provision of essential services within each area.

6. The development of a staffing plan and management structure for the R/C service and its component units.

7. Before and during an emerging crisis, recruitment, orientation, and training for any unfilled staff positions in the host area's R/C organization.

To be more specific the following functions together with bookkeeping functions are used:

Select Participants in Host County Planning.

Define the boundaries of the risk area.

Define the boundaries of the host area.

Determine the size of the total risk area (evacuee) population.

Describe the evacuee population.

Allocate the evacuee population.

Describe host county facilities.

Coordinate shelter plans for evacuees and local residents.

Rank-Order the facilities available to lodge, shelter, and feed evacuees.

Allocate evacuees to congregate lodging, shelter and feeding facilities.

Divide the county into R/C divisions, districts, and lodging sections.

Enumerate R/C jurisdictions and select headquarters, facilities, reception centers, and rest areas.

Develop general tables of organizations and job descriptions for all management positions in R/C service.

Describe the organizational structure of each area R/C unit.

Develop an operational checklist of R/C responsibilities and actions before and during a crisis.

Complete main plan.

Continue development of the county R/C plan and standby organization.

It should be noted that these functions correspond closely to the steps found in volume II of [1].

These R/C functions are not presented in a separate control map but are intergrated in the existing control map for "Plan to relocate industrial labor force." The resulting design is a unified subsystem of civil defense.

The relationship between the system "Industrial Relocation Planning" and "Reception and Care Planning" is a complex one. This is true in the sense that one system is not just a subsystem of the other, but that "Reception/Care Planning " represents a further decomposition of "Industrial Relocation Planning" on many levels. To make the relationship between certain functions of "Industrial Relocation Planning" and "R/C Planning" clear, we provide the following:

Desk-top initial allocation:

Select participants in host area planning.

Precisely define the boundaries of the risk area.

Precisely define the boundaries of the host area.

Describe the evacuee population to be hosted in the area.

Divide the area into R/C divisions.

On-site analysis of risk area:

Determine the size of the total risk area (evacuee population)

Describe the evacuee population in detail.

On-site analysis of host area:

Rank-order the facilities available to lodge, shelter, and feed evacuees

Enumerate R/C jurisdictions.

Divide the area into R/C divisions.

Describe host county facilities.

Plan for reception and care organization:

Coordinate shelter plans for evacuees and local residents.

Develop general tables of organizations and job descriptions for all management positions inthe area R/C service.

Describe the organizational structure of each area's R/C unit.

Develop an operational checklist of R/C responsibilities and actions before and during a crisis.

Complete Main Plan.

Continue development of the area R/C plan and standby organization.

The above should be interpreted to mean that, say, "Determine the size of the total risk area (evacuee) population" and "Describe the evacuee population in detail" will be in the decomposition of "On-site analysis of risk area." The other functions are interpreted in the same way. The result is, of course, a more detailed design of the system.

To understand the new design more clearly, we now provide a detailed explanation of those nodes that have been modified, i.e., that have been further decomposed. The first is "Desk-top initial allocation." Originally, it was not decomposed further but we fully expected that it should be. (That is, it is a pseudomodule. Discussion concerning these will be provided below.) The inputs to the function are "company information", "CRP", census data" and "risk area information". The outputs are "analyzed number of people (to be evacuated)", "participants (in host area planning)," "division of risk area," and "boundaries of risk area." In order to compute "Desk-top initial allocation," the functions "Define boundaries of risk area," Determine divisions of risk area," "Select participants in host-area planning," and "Determine number abd description of people to be evacuated" must be "computed." The first two of these will produce "boundaries of risk area" and "divisions of risk area," respectively. In order to "Select participants in host area planning," the functions "Select area R/C Coordinator," "Select director of shelter planning and allocation," and "Select deputy coordinator for welfare shelter operation" must be executed. These will provide the necessary participants in host area planning. "Determine number and description of people to be evacuated" produces the obvious output with "Description of people to be evacuated" meaning certain occupational information, addresses, etc. of the potential evacuees.

As mentioned above, the function "On-Site analysis of risk area" is decomposed into the two functions "Determine the size of the total risk area" and "Describe the evacuee population in detail." These two functions provide a more detailed analysis of the evacuee population that had been established in "Desk-top initial allocation." "Determine the size of total risk area" provides a better estimate of the number of people to be evacuated while "Describe the evacuee population in detail" will provide descriptive information concerning the evacuess and will also note any special problems, e.g., large population of elderly.

"On-Site analysis of host area" is revised in that the outputs are "hosting capabilities" (as in the earlier control map), "host area divisions," "enumeration of R/C jurisdictions," and "ordered facilities." These are obtained by "Determine hosting capabilities," "Divide host area into R/C divisions," "Enumerate R/C jurisdictions," and "Rank-Order facilities available," respectively. Note that "Rank-Order facilities available" must precede "Enumerate R/C jurisdictions and select facilities" which precedes "Divide the host area into R/C divisions." The reason for these precedence relations is that the output of "Rank-Order facilities" is input to "Enumerate R/C jurisdictions and select facilities." The output of this function is then input to "divide the host area into R/C divisions".

The node "Plan for reception and care organization" is found in both "Industrial Relocation" design and the integrated design. In "Industrial Relocation" the decomposition obtained basically the functions "Review" (the set of requirement statements), "Compare" (sources available and set of requirement statements), and "Argument existing capabilities" (which produced "HAP" as output). [1] provides the basis for several functions that enabled a further decomposition of "Plan for R/C organization." These functions are "Coordinate shelter plan for evacuees and local residents," "Develop general tables of organization and job descriptions for all management positions in the area R/C service," "Describe the organizational structure of each area R/C unit," "Develop an operational checklist of R/C responsibilities and actions before and during a crisis," "Complete main plan," and "Continue development of the are R/C plan."

As noted above, these functions are in the decomposition of "Plan for reception and care organization." This should seem natural since, intuitively, these functions are generally high-level organizational planning activities. In fact, the last two functions are the actual development of the main plan and the continuing development of such a plan, both of which would not occur in a lower level of civil-defense planning.

An important point to make is that "Continue development of plan" rather than "Complete main plan" outputs HAP. The "main plan" (the output of "Complete main plan") provides the basic information and general statements of R/C purposes and orgainzation. It not only acquaints those who are interested in R/C planning, but it also provides the activities (functions) for those who are crucially involved.

HAP, however, cannot remain static. It continually needs to be improved or updated due to population shifts, relocating industries, changing R/C staff, among other factors. So in this respect the control map accurately reflects this. HAP is not the output of "Complete main plan," otherwise, it would remain fixed. "HAP" is the output, though, of "Continue development of plan," which indicates a plan that is up-to-date and dynamic.

As noted above and in "On Industrial Relocation," Industrial Relocation contained many pseudomodules. (A pseudomodule is a module that is not fully decomposed, but is expected to be so later,) "Desk-top initial allocation" is one such example. In the original control map, this particular node had the form:

"analyzed number of people to be evacuated" = Desk-top initial (co. info, CRP, c.d., risk area info.) allocation "

The integrated design shows that this particular node now becomes: Figure 1.

Note that the level of decomposition and, therefore, the level of detail is greater in the integrated design than in the original control map.

In addition to "Desk-top initial allocation," "On-site analysis of host area," "On-site analysis of risk area," and "Plan for reception and care organization" have been more fully decomposed. Therefore, the design of the system is more complete. Clearly, this aids the planners and allows for a more easily implementable system. (See Figures 2 and 3).

One observation that should be emphasized is that only minor modifications were needed in the integration of R/C planning with Industrial Relocation Planning. The inputs and outputs to both the Industrial Relocation System and to the integrated system are the same. The inputs are co, info, OAF, CRP, census data, set of requirement statements, r.a. info., and add. info. The output is composed of number and determination of people to be evacuated, RAP, and HAP. As is clear from the control maps, the two systems have many of the same functions in common.

To look at one example in detail, consider "Plan for reception and care organization." This function has the inputs co. info., CRD, c.d., set of reg!s, r.a. info ., add, info., better estimate, spec. problems, (suitable) hosting location, host area survey, and hosting capabilities. The output is host area plan. Intuitively, it was this function that is related to various R/C organizational functions. Any steps found in [1] that deal with the organizational structure should be found in the decomposition of this function. And, indeed, this is the case. Steps 11-16 of [1] are in the decomposition of "Plan for R/C organization" (as well as other functions in the original decomposition.

This observation together with the understanding of the design effort itself provides evidence for a claim made in "On Industrial Relocation". There it was stated, "Another important point is that HOS methodology is universal. In other words, any subsystem of civil defense can be specified using control maps. Thus, the methodology facilitates the ease by which various civil defense systems can be specified and verified. It would be cumbersome to have several methodologies each defining some (but not all) of the subsystems. This would require a knowledge of several methodologies (as compared to one) in order to work within civil defense systems " [2]. In constructing this control map, only minor modifications had to be made to the original map. Nevertheless, it is via HOS control maps that an integrated system of civil defense can be designed.

In connection with this sytem of Industrial Relocation/Reception and Care Planning system, there are several areas that still have to be addressed. These are the transportation system, communication system, and the system specifying the distribution of the relocated population. The transportation system would involve the transportation of the maximum number of people in the least amount of time. In [1], this is stated in Step 2.3. The means of transportation as well as the routes must be explicitly specified in the planning stage to guarantee a reliable system, if ever needed.

The transportation system for Industrial Relocation can also be integrated within the existing design. It would be part of the decomposition of "Provide Transportation." This function is part of the risk area plan. For more on the requirements and problems of a transportation system, see [3].

The communication system provides another problem. There must be some way of providing communication between the host area and risk area during and after evacuation. While evacuation is being carried out, it is important that information concerning, say, transportation (bottlenecks, etc.) be available to staging areas in the risk area so other alternatives could be considered. Even after relocation, communication between the risk area and host area must remain open so that those whose jobs keep them in the risk area or those commuting between the two will be informed as to the latest developements.

One requirement of a system of communication is that it must be modular. This would imply that if a section of the communication network is rendered inoperative, information could still flow around the downed part of the system. The value of this is obvious.

Also under the Transportation node is the problem of the distribution of the population. This is an enormous problem in view of such large, highly populated cities as New York, Boston, and Washington, D.C. The system must be set up such that the people of a risk area are evacuated to a host area in a way that everyone has a host area assigned, but that no host area is overcrowded. An overcrowded area would be one whose facilities and services could not meet the demands of all the people.

This type of problem cannot be done just on a local level. A large system must be designed so that planning from various risk areas do not conflict. For instance, area H may accomodate the people from either area R_1 or R_2, but not both. The idea of transporting the people from R_1 or R_2 may seem feasible to planners of R_1 and R_2, respectively, but there must be some mechanism preventing both from formulating this plan. Otherwise, it could not support people from both R_1 and R_2, a potentially tragic situation. Other problems (food availability, housing, etc.) must also be considered.

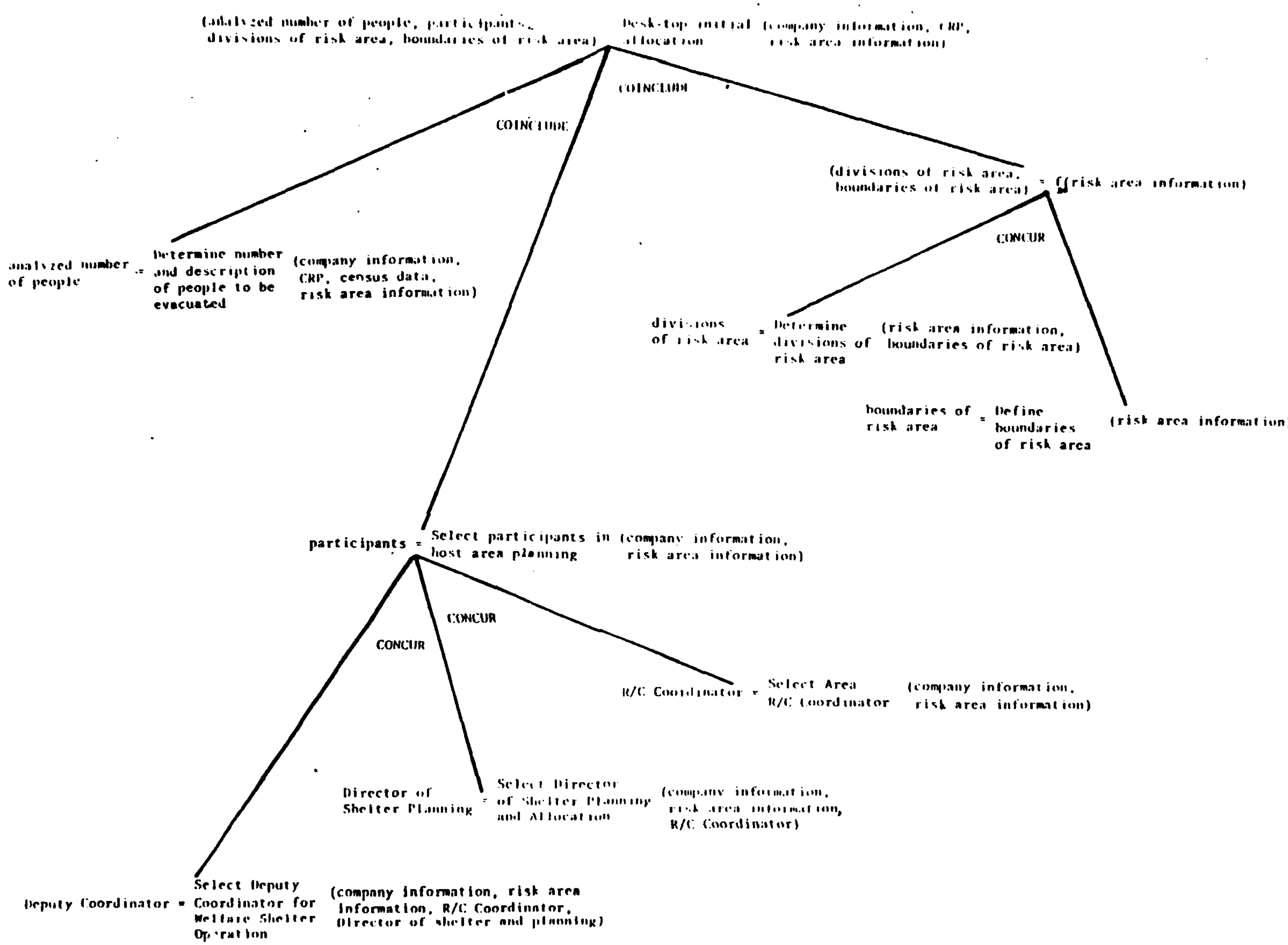


Fig. 1

DESK-TOP INITIAL ALLOCATION

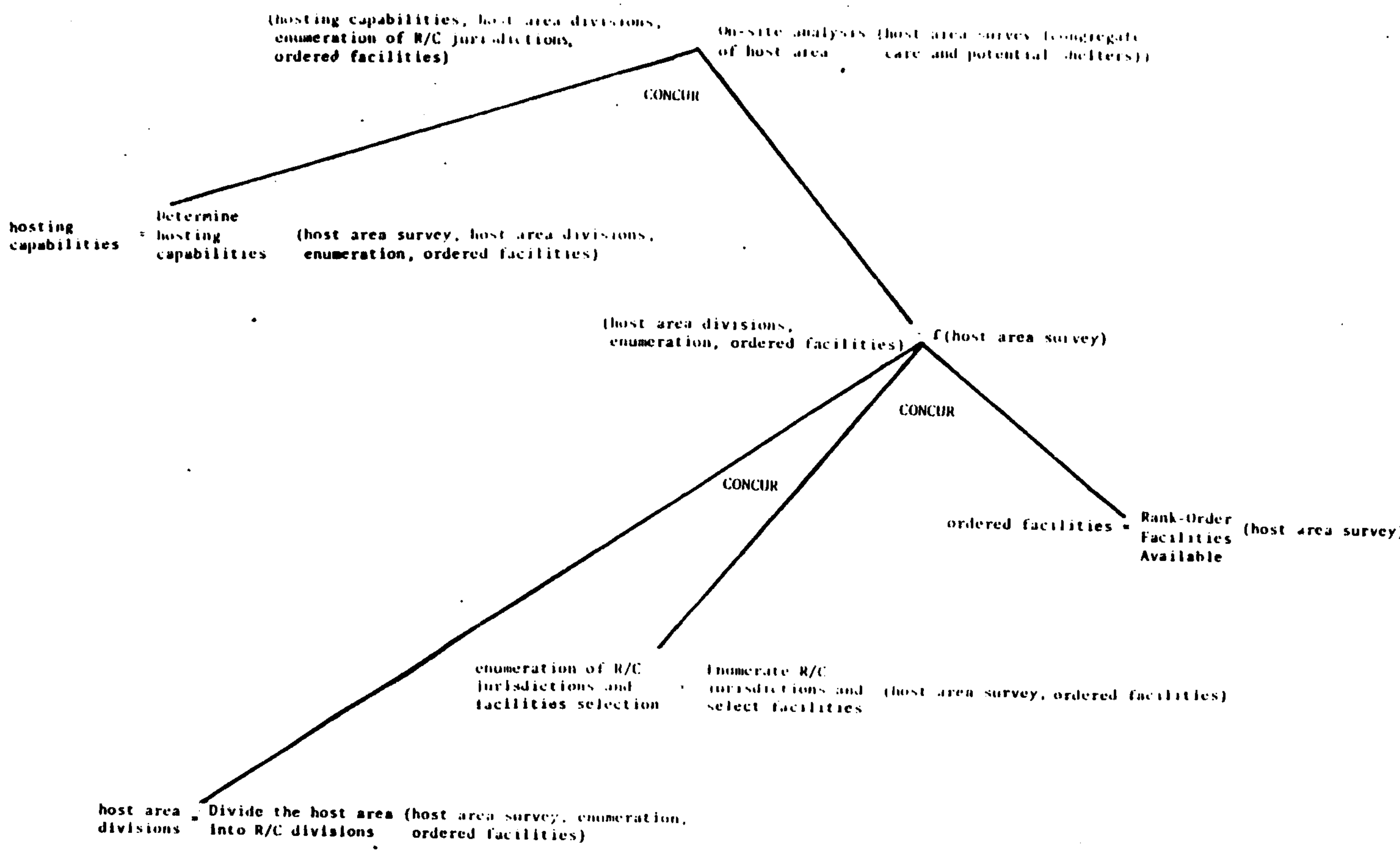


Fig. 2

ON-SITE ANALYSIS OF HOST AREA

(better estimate of number of people, determination of people, special problems) = On-site analysis of risk area (company information, CRP, census data, risk area information, analyzed number of people)

CONCUR

better estimate of number of people = Determine the size of total risk area (company information, census data, risk area information, analyzed number of people)

(determination of people, special problems) = Describe the evacuee population in deatail (company information, CRP, census data, risk area information, analyzed number of people, better est.)

Fig. 3

ON-SITE ANALYSIS OF RISK AREA

REFERENCES

[1] Defense Civil Preparedness Agency, Reception and Care Planning Guidance for Host Communities, Department of Defense, 1977.

[2] Kuhns, R., On Industrial Relocation, Higner Order Software, Inc., Cambridge, MA, 1979

[3] Kuhns, R., Preliminary Transportation Systems for Civil Defense, DCPA Memo No. 9, Higher Order Software, Inc., Cambridge, MA, 1978.

(number and determination of people to be evacuated, risk area plan (RAP), host area plan (HAP)) = Plan to relocate industrial labor force (company information, org... ass...

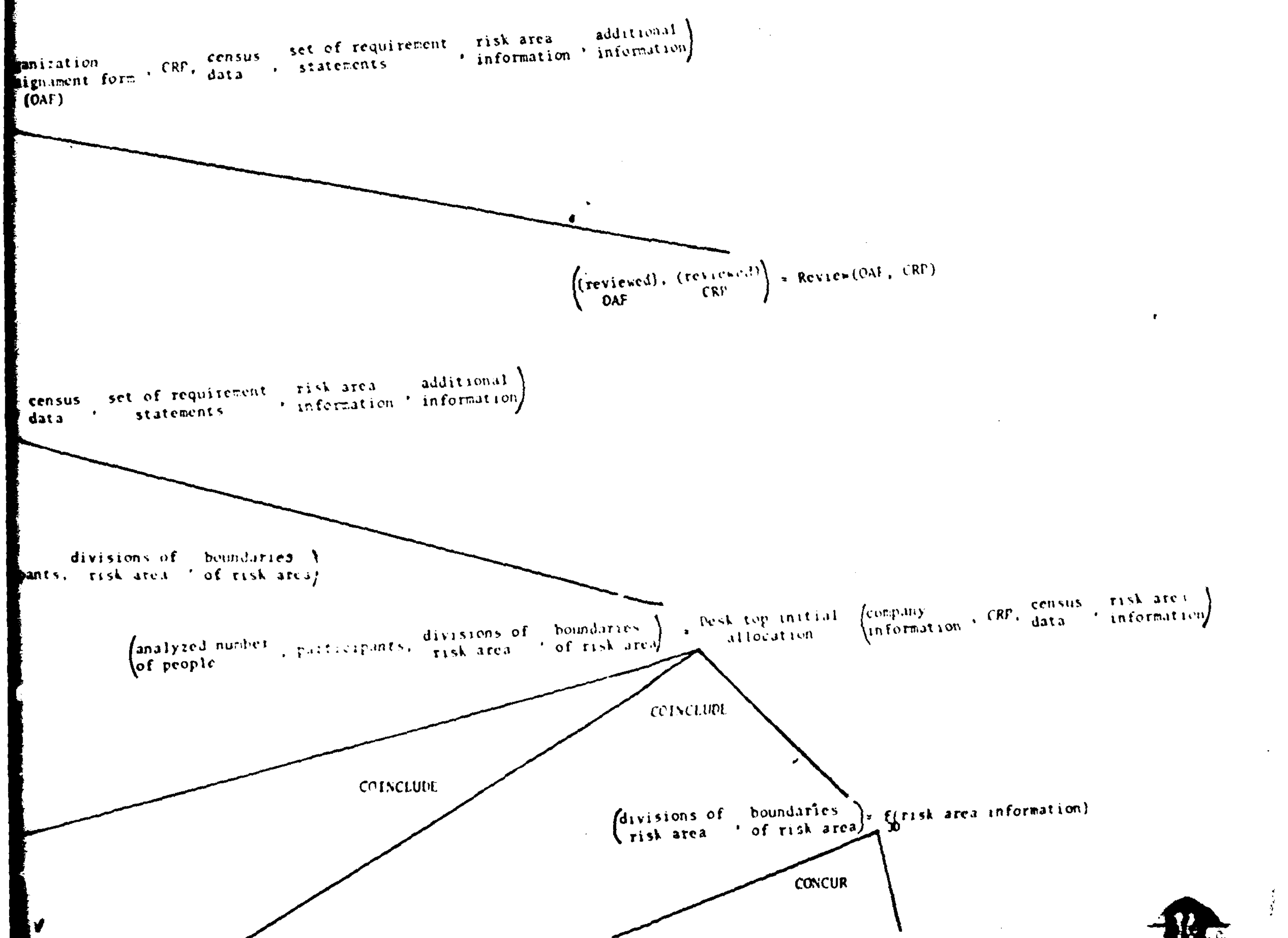
COJOIN

(number and determination of people to be evacuated, RAP, HAP) = f_1 (company information, OAF, CRP, ...

COJOIN

(number and determination of people to be evacuated, RAP, HAP) = f_2 (company information, OAF, CRP, set of requirement statements, risk area information, additional information, analyzed number of people, partic...

2



anization alignment form (OAF), CRP, census data, set of requirement statements, risk area information, additional information)
((reviewed) OAF, (reviewed) CRP) = Review(OAF, CRP)
census data, set of requirement statements, risk area information, additional information)
pants, divisions of risk area, boundaries of risk area)
(analyzed number of people, participants, divisions of risk area, boundaries of risk area) = Desk top initial allocation (company information, CRP, census data, risk area information)
COINCLUDE
COINCLUDE
(divisions of risk area, boundaries of risk area) = f(risk area information)
CONCUR

number and description of people to be evacuated = Determine number and description of people to be evacuated (company information, CRP, census data, risk area information)

Participants = Select participants in host area planning (company inform

CONCUR

CONCUR

deputy coordinator for welfare shelter operation = Select deputy coordinator for welfare shelter operation (company information, r.a. info, R/C coordinator, director of shelter planning and allocation)

director of shelter planning and allocation = Select director of shelter planning and allocation (company informati

3

divisions of risk area = Determine divisions of risk area (risk area information, boundaries of risk area)

boundaries of risk area = Define boundaries of risk area(risk area information)

formation, risk area information)

R/C Coordinator = Select R/C Coordinator (company information, risk area information)

ation, risk area information, R/C coordinator)

4

(number and determination of people to be evacuated , RAP, HAP) = f_2 (company information , OA

COJOIN

(RAP, HAP) = f_3 (co. info, OAF, CRP, set of req's, r.a. info, add. info, analyzed no., participants, div. of r.a., boun. of r.a., bet. est., det. of people, spec. prob

COJOIN

(det.

host area = Select host area (co. in

(RAP, HAP) = f_4 (co. info, OAF, CRP, set of req's, r.a. info, add. info, analyzed no., participants, div. of r.a., boun. r.a., bet. est., det. of people, spec. prob., host area)

COJOIN

partially filled in OAF = Make notations(co. in

(RAP, HAP) = f_5 (co. info, partially filled in OAF, set of req's, r.a. info, add. info, analyzed no., participants, div. of r.a., boun. of r.a., bet. est., det. of people, spec. prob.)

COJOIN

host area survey = Survey host area(host area)

, HAP) = f_6 (co. info, partially filled in OAF, CRP, set of req's, r.a. info, add. info, analyzed no., participants, div. of r.a., bound. of r.a., bet. est., det. of people, spec. problems, host area, host area survey) ion , OAF, CRP, set of requirements statements , risk area information , additional information , analyzed number of people , participants, divisions of risk area , boundaries of risk area)

IN

(better estimate of number of people , determination of people , speci problems) = On-site analysis of risk area (co. info., CRP, census data , r.a. info, analyzed no. of people)

CONCUR

ec. prob.)

better estimate of number of people = Determine the size of total risk area (co. info, c.d., r.a. info, analyzed

(det. of people, spec. prob.) = Describe the evacuee population in detail (co. info, CRP, c.d., r.a. info, analyzed no., bet. est.)

(co. info, CRP, bet. est., spec. prob.)

ea)

o. info, OAF, CRP, add. info, bet. est.)

(RAP, HAP) = f_6 (company information, partially filled in OAF, CRP, set of requirement statements, risk area information, additi[...] inform[...]

COJOIN

host. cap. = Determine host. cap. (

(RAP, HAP) = f_7 (co. info, partially filled in OAF, CRP, set of req's, r.a. info, add. info, analyzed no., pa[...]
bet. est., det. of people, spec. prob., h.a., h.a. survey, host. cap., h.a. div., enum., ord[...]

COJOIN

Q = Is the hosting area su[...]

2

tional formation, analyzed number of people, participants, divisions of risk area, boundaries of risk area, better estimate of number of people, determination of people, special problems, host area, host area survey)

(hosting capabilities, host area divisions, enumeration of R/C jurisdictions, ordered facilities) = On-site analysis of host area (host area survey (congregate care and potential shelters))

CONCUR

(h.a. divisions, enumeration, ordered facilities) = f(host area survey)

(h.a. survey, h.a. divisions, enum., ord. fac.)

CONCUR

CONCUR

h.a. div. = Divide the host area into R/C divisions (h.a. survey, enum., ord. fac.)

ord. fac. = Rank-Order Facilities Available (h.a. survey)

enumeration of R/C jurisdictions and facilities selection = Enumerate R/C jurisdictions and select facilities (h.a. survey, ord. fac.)

rticipants, div. or r.a., fac.)

fficient? (co. info, bet, est., spec. prob., h.a., h.a. survey, host, cap., h.a. div, enum., ord. fac.)

(RAP, HAP) = f_8 (co. info, partially filled in OAF, CRP, set of req's, r.a. info, add. info, analyzed no., participants, div. of r.a., bet. est., det. of people, spec. prob., h.a., h.a. survey, host. cap., h.a. div., enum.,

COJOIN

hosting location = f_9

Q = No

hosting location = Change to more suitable location (co. info, h.a.)

(RAP, HAP) = f_{10} (co. info, partially filled in OAF, CRP, set of req's, r.a. info, add. info, analyzed no., participants, div. of r.a., bet. est., det. of people, spec. prob. h.a., h.a. survey, host. cap., h.a. div., enum., ord. fac., host. loc.)

COJOIN

completed OAF = Make Notation(partially filled in OAF,

(RAP, HAP) = f_{11}(co. info, completed OAF, CRP, set of req's, r.a. info, add. info, analyzed no., participants, div. of r.a., bet. est., det. of people, spec. prob., h.a., h.a. survey, host. cap., h.a. div., enum., ord. fac., host. loc.)

3

, ord. fac., Q)

$_9$(co. info, h.a., Q)

COOR

Q = Yes

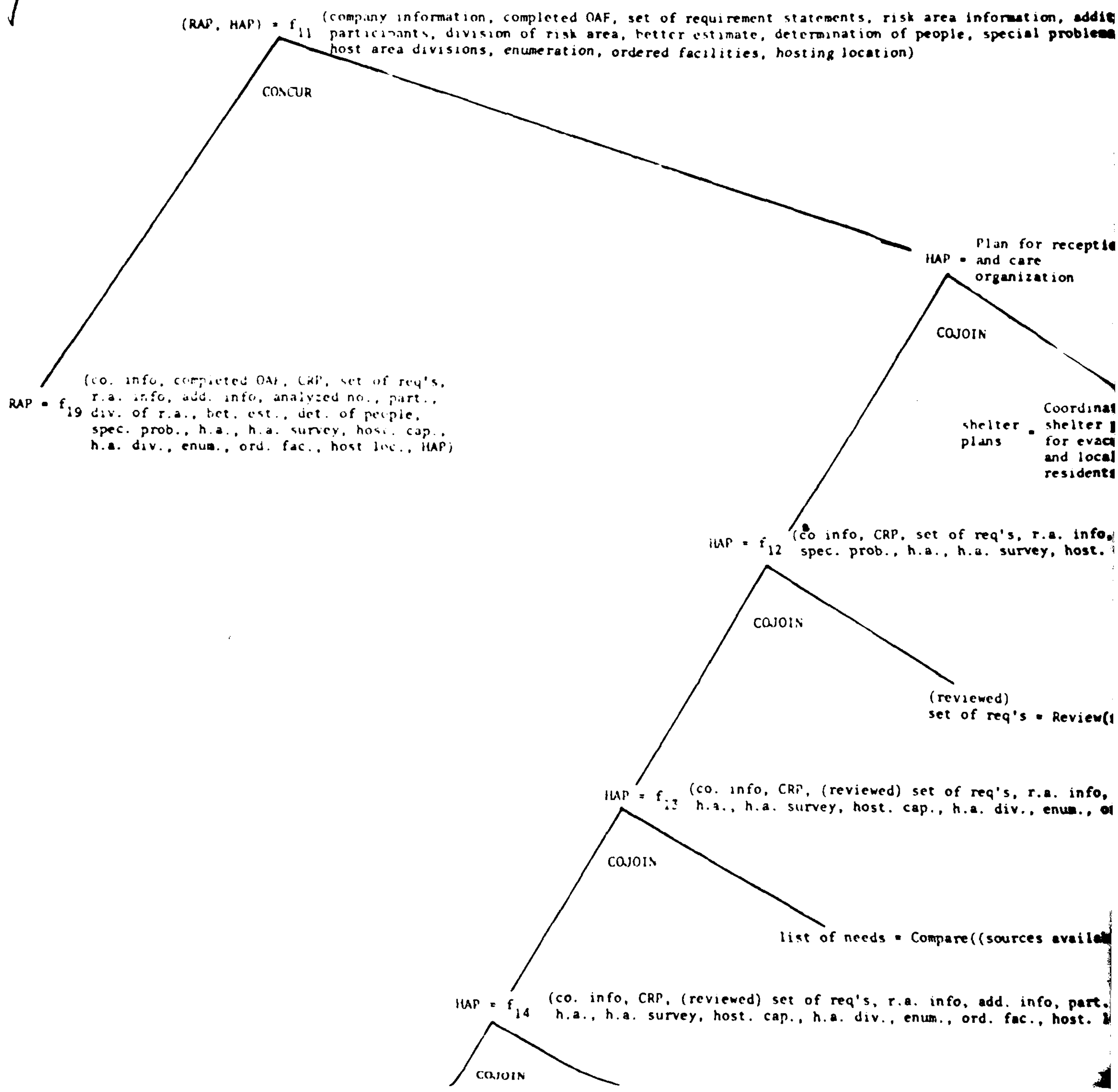
hosting location = Select suitable hosting location (co. info, h.a.)

a.,

, host. loc.)

3

4



(RAP, HAP) = f_{11} (company information, completed OAF, set of requirement statements, risk area information,
participants, division of risk area, better estimate, determination of people, special problems
host area divisions, enumeration, ordered facilities, hosting location)
CONCUR
RAP = f_{19} (co. info, completed OAF, CRP, set of req's, r.a. info, add. info, analyzed no., part., div. of r.a., bet. est., det. of people, spec. prob., h.a., h.a. survey, host. cap., h.a. div., enum., ord. fac., host loc., HAP)
HAP = Plan for recepti
and care
organization
COJOIN
shelter plans = Coordinat
shelter
for evac
and local
residents
HAP = f_{12} (co info, CRP, set of req's, r.a. info,
spec. prob., h.a., h.a. survey, host.
COJOIN
(reviewed)
set of req's = Review(
HAP = f_{13} (co. info, CRP, (reviewed) set of req's, r.a. info,
h.a., h.a. survey, host. cap., h.a. div., enum.,
COJOIN
list of needs = Compare((sources availa
HAP = f_{14} (co. info, CRP, (reviewed) set of req's, r.a. info, add. info, part.
h.a., h.a. survey, host. cap., h.a. div., enum., ord. fac., host.
COJOIN

2

dditional information, analyzed number of people
lems, host area, host area survey, hosting capabilities,

eption (co. info, CRP, set of req's, r.a. info, add. info, part.,
bet. est., det. of people, spec. prob., h.a., h.a. survey,
host, cap., h.a. div., enum., ord. fac., host. loc.)

rdinate
lter plans (co. info, bet. est., det. of people, spec. prob., h.a.,
evacuees h.a. survey, host. cap., ord. fac., host loc.)
local
idents

info, add. info, part., bet. est., det. of people,
ost. cap., h.a. div., enum., ord. fac., host loc., shelter plans)

view(set of requirement statements)

info, add. info, part., bet. est., det. of people, spec. prob.,
., ord. fac., host. loc., shelter plans, list of needs)

ailable) host area survey, (reviewed) set of req's)

part., bet. est., det. of people, spec. prob.,
t. loc., shel. plans, list of needs)

AD-A084 741 HIGHER ORDER SOFTWARE INC CAMBRIDGE MA F/G 15/3
APPLICATION OF A FORMAL SYSTEMS METHODOLOGY TO CIVIL DEFENSE.(U)
MAR 80 R KUHNS, S CUSHING, L VAINA, M ZELDIN DCPA01-78-C-0164
UNCLASSIFIED TR-26 NL

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END
DATE
FILMED
6-80
DTIC

added resources = Augment existing capabilities (co. info, CRP,
spec. prob., h.

HAP = f_{15} (co. info, CRP, (reviewed) set of req's, r.a. info, part., bet.
h.a., h.a. survey, host. cap., h.a. div., enum., ord. fac., host

COJOIN

organize tables and job descriptions = Develop general tables of organization and job descriptions

HAP = f_{16} (co. info, CRP, (reviewed) set of req's, r.a. info, add. info, part., bet. est.,
h.a., h.a. survey, host. cap., h.a. div., enum., ord. fac., host. loc., shel. pl
organize tables and job descriptions)

COJOIN

organizational structure = Describe organizational structure of R/C units (co. info, h.a. survey, h.
list of needs, org. tab.

HAP = f_{17} (co. info, CRP, (reviewed) set of req's, r.a. info, add. info, part., bet. est., det. of people,
host. cap., h.a. div., enum., ord. fac., host loc., shel. plans, list of needs, add. res., org.

COJOIN

operational checklist = Develop operational checklist of R/C responsibilities + actions (co. info, CRP, bet.
shel. plans, add. re

HAP = f_{18} (co. info, CRP, (reviewed) set of req's, r.a. info, add. info, part., bet. est., det. of people, spec. prob., h.a
host. cap., h.a. div., enum., ord fac., host. loc., shel. plans, list of needs, add. res., org. tab. + job. des

COJOIN

Main Plan = Complete Main Plan (co. info, CRP, (reviewed) set of req's, r.a. info, add. info, part.,
host cap., h.a. div., enum., ord. fac., host. loc., shel. plans, list
op. checklist)

HAP = Continue Development of Plan (co. info, CRP, (reviewed) set of req's, r.a. info, add. info, part., bet. est., det. of people, spec. prob.,
host. cap., h.a. div., enum., ord. fac., host. loc., shel. plans., list of needs, add. res., org. tab. + job
op. checklist, main plan)

3

eviewed) set of req's, r.a. info, add. info, part., bet. est., det. of people,
., h.a. survey, host. cap., host. loc., shel. plans, list of needs)

t., det. of people, spec. prob.,
loc., shel. plans, list of needs, additional resources)

(co. info, CRP, part., bet. est.,
det. of people)

et. of people, spec. prob.,
ns, list of needs, additional resources,

a. div., enum., ord. fac., host. loc.,
+ job. des.)

pec. prob., h.a., h.a. survey,
ab. + job. des., org. structure)

est., det. of people, enum., ord. fac.,
., org. tab. + job. des., org. struc.)

., h.a. survey,
., org. struc., op. checklist)

t. est., det. of people, spec. prob., h.a. h.a. survey,
of needs, add. res., org. tab. + job des., org. struc,

h.a., h.a. survey,
des., org. struc.,

4

4

RAP = f_{19} (company information, completed Organization Assig
analyzed number of people, participants, divisions
host area survey, hosting capabilities, host area

COJOIN

(reviewed) set of req's = Revi

RAP = f_{20} (co. info, completed OAF, CRP, set of req's, r.a. info, add. info, analyzed
det. of people, spec. prob., h.a., h.a. survey, host. cap., h.a. div., enu

COJOIN

augmentation plans = Plan to augment needs (co. info, (revi

RAP = f_{21} (co. info, completed OAF, CRP, set of req's, r.a. info, add. info, analyzed no., part., div.
spec. prob., h.a., h.a. survey, host. cap., h.a. div., enum., ord. fac., host. loc., HAP,

COJOIN

ment Form, CRP, set of requirements statements, risk area information, additional information,
of risk area, better estimate, determination of people, special problems, host area,
divisions, enumeration, ordered facilities, hosting location, Host Area Plan)

view(set of req's statements)

nd no., part., div. of r.a., bet. est.,
num., ord. fac., host. loc., HAP)

viewed) set of req's, r.a. info)

iv. of r.a., bet. est., det. of people,
, augmentation plans)

Movement Plans = Plan for Movement (co. info, completed OAP, CRP, set of req's r.a. info, add. info, part., div. of r.a., bet. est., det. of people, spec. prob., h.a., h.a. div., host. loc., HAP)

COJOIN

Q = Is the risk area large or small?(co. info, r.a. info, bet. est.)

Movement Plans = f_{22} (co. info, completed OAP, CRP, set of req's, r.a. info, add. info, part., div. of r.a., bet. est., det. of people, spec. prob., h.a., h.a. div., host. loc., HAP, Q)

COOR

Q = large

Q = small

Movement Plans = Formulate Plans (co. info, completed OAP, CRP, set of req's, r.a. info, add. info, part., div. of r.a., bet. est., det. of people, spec. prob., h.a., h.a. div., host. loc., HAP)

RAP = f_{24} (co. info, completed OAF, CRP, set of req's, r.a. info, analyzed no, part , div. of r.a., bet. est., det. of people, spec. prob., h.a., h.a. survey, host. cap., h.a. div., enum., ord. fac., host loc., HAP, aug. plans, movement plans)

COJOIN

CO[JOIN]

Movement Plans = Formulate Plans (co. i[...] bet. [...]

RAP = Formulate RAP (company information, completed OAF, CRP, set of requirement statements, additional information, analyzed number of people, participants, divisions of risk area, better estimate, determination of people, special problems, host area, host area survey, hosting capabilities, host area divisions, enumeration, ordered facilities, hosting location, Host Area Plan, augmentation plans, movement plans, support plans)

Support Plans = Provide Support (co. info, CRP, [...] bet. est, det. [...]

COJOIN

Various support = [...]

Support Plans = f_{25} (co. info, CRP, set of req's, r.a. [...] spec. prob., h.a., h.a. div., host[...]

COJOIN

Security Support = Provide [...] (fire an[d ...]

Support Plans = f_{26} (co. info, CRP, set of req's, r.a. info, analyzed [...] det. of people, spec. prob., h.a., h.a. div., host[...]

COJOIN

Shelter & Tactical Evacuation Plans = Provide direct-[...] effect shelters [...] tactical evacuat[...]

Support Plans = Coordinate the plans (co. info, CRP, set of req's, r.a. info, analyzed no., pa[...] spec. prob., h.a., h.a. div., host. loc., HAP, trans. se[...]

3.

transport schedule = Schedule transport (co. info, CRP, r.a. info, bet. est., det. of people, spec. prob., h.a., h.a. div., host. loc., HAP)

info, completed, OAF, CRP, set of req's, r.a. info, add. info, part., div. of r.a., est., det. of people, spec. prob., h.a., h.a. div., host. loc., HAP, transport schedule)

, set of rq's, r.a. info, analyzed no., part., div. of r.a., . of people, spec. prob., h.a., h.a. div., host. loc., HAP, transport schedule)

Provide food, medical, fuel, + repair support (co. info, CRP, set of req's, r.a. info, analyzed no., div. of r.a., bet. est., det. of people, h.a., h.a. div., host loc., HAP, trans. sched.)

. info, analyzed no, part., div. of r.a., bet. est, det. of people, st. loc., HAP, trans. sched., various support)

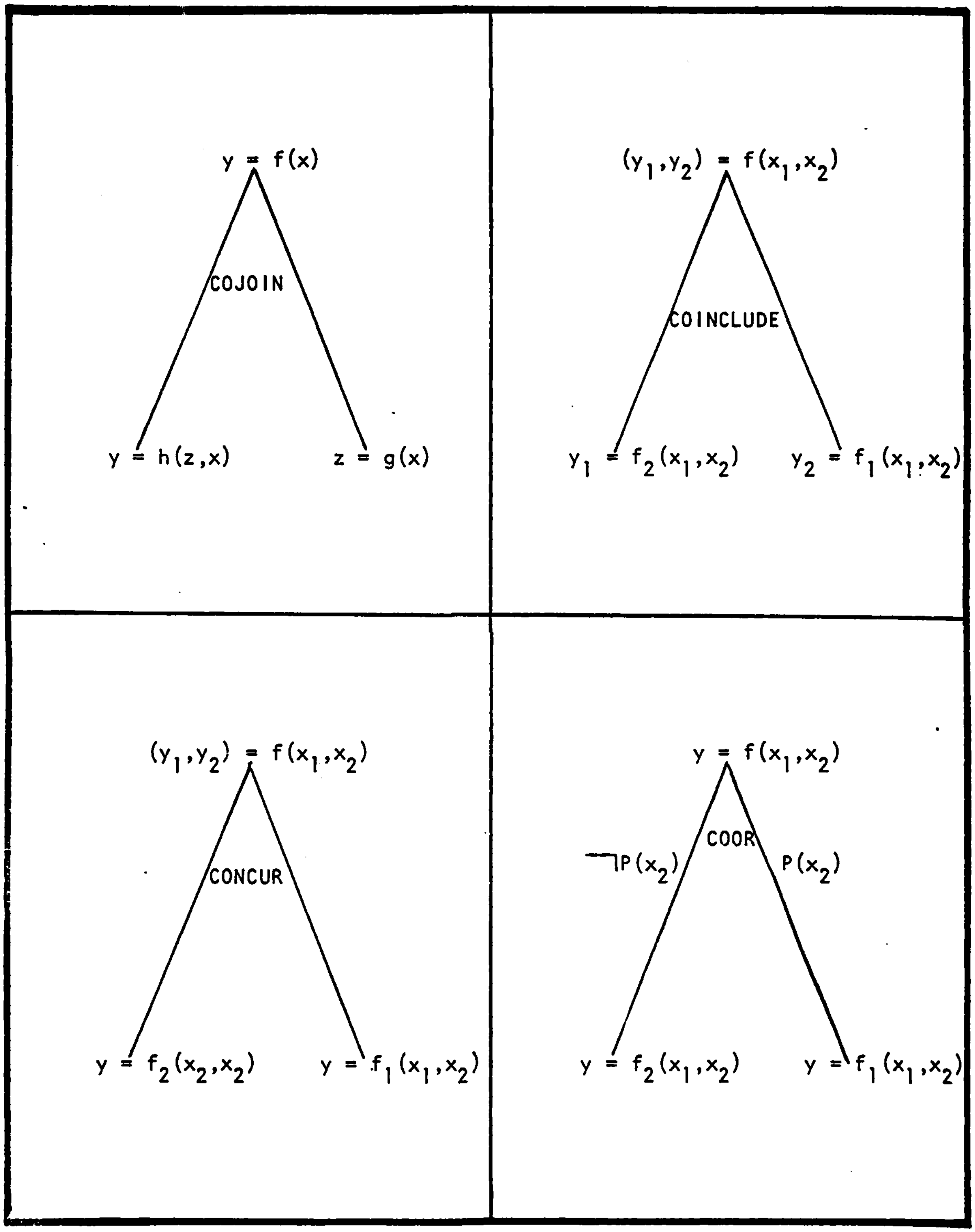
Security (and police) (co. info, CRP, set of req's, r.a. info, analyzed no., part., div. of r.a, bet. est., det. of people, spec. prob., h.a., h.a. div., host, loc., HAP, trans. sched., var. sup.)

d no., part., div. of r.a., bet. est., ost, loc., HAP, trans. sched., var. sup., security support)

t- rs & tion (co. info, CRP, set of req's, r.a. info, analyzed no. , part., div. of r.a., bet. est., det. of people, spec. prob., h.a., h.a. div., host. loc., HAP, trans. sched., var. sup., security support)

part., div. of r.a., bet. est., det. of people, sched., var. sup., sec. sup., shelter and tactical evacuation plans)

4.


$y = f(x)$
COJOIN
$y = h(z,x)$
$z = g(x)$
$(y_1,y_2) = f(x_1,x_2)$
COINCLUDE
$y_1 = f_2(x_1,x_2)$
$y_2 = f_1(x_1,x_2)$
$(y_1,y_2) = f(x_1,x_2)$
CONCUR
$y = f_2(x_2,x_2)$
$y = f_1(x_1,x_2)$
$y = f(x_1,x_2)$
COOR
$\neg P(x_2)$
$P(x_2)$
$y = f_2(x_1,x_2)$
$y = f_1(x_1,x_2)$

KEY

ADD. INFO	- ADDITIONAL INFORMATION
ADD. RES.	- ADDITIONAL RESOURCES
ANALYZED NO.	- ANALYZED NUMBER OF PEOPLE
AUG. PLANS	- AUGMENTATION PLANS
BET. EST.	- BETTER ESTIMATE
BOUN. OF R.A.	- BOUNDARIES OF RISK AREA
C.D	- CENSUS DATA
CO. INFO	- COMPANY INFORMATION
DET. OF PEOPLE	- DETERMINATION OF PEOPLE
DIV. OF R.A.	- DIVISIONS OF RISK AREA
ENUM.	- ENUMERATION
H.A.	- HOST AREA
H.A. DIV.	- HOST AREA DIVISIONS
HAP	- HOST AREA PLAN
H.A. SURVEY	- HOST AREA SURVEY
HOST. CAP.	- HOSTING CAPABILITIES
HOST. LOC.	- HOSTING LOCATION
MOVE. PLANS	- MOVEMENT PLANS
OAF	- ORGANIZATIONAL ASSIGNMENT FORM
ORD. FAC.	- ORDERED FACILITIES
ORG. TAB. & JOB. DES.	- ORGANIZATIONAL TABLES AND JOB DESCRIPTIONS
PART.	- PARTICIPANTS
R.A. INFO	- RISK AREA INFORMATION
RAP	- RISK AREA PLAN
SEC. SUP	- SECURITY SUPPORT
SET OF REQ'S	- SET OF REQUIREMENTS STATEMENTS
SHEL. PLANS	- SHELTER PLANS
SPEC. PROB.	- SPECIAL PROBLEMS
TRANS. SCHED.	- TRANSPORTATION SCHEDULE
VAR. SUP.	- VARIOUS SUPPORT

SECTION V

A MODEL OF COMMUNICATION

A MODEL OF COMMUNICATION

It is clear, by now, that a model for communication can be built only within the framework of language use. To ensure a good "communication," [Grice] proposes four "maxims" that he groups under the Cooperative Principle.

(1) Maxim of Quantity: Make the contribution to communication as informative as is required for the current purpose of the exchange.

(2) Maxim of Quality: Make the contribution one that is true, in that the contribution should coincide, as far as possible, with the reality of the facts. In some cases, the exact state of the facts are not known, and it is then necessary to make approximations, based on observations, expectations, hopes, etc.

(3) Maxim of Relation: The content of the communication should be relevant to the goal of communication.

(4) Maxim of Manner: The participants engaged in the process of communication should avoid, as much as possible, ambiguity.

I call these principles external, because they monitor every good or correct communicative action. I will call internal principles of communication those principles referring to (a) the individuals performing the communication, which as a speech act has a certain illocutionary force and a prelocutionary effect; and (b) the place and time of communication.

The first internal principle of communication refers to the relation which is established within the context of communication. Therefore, for example, we can talk about the relation of subordination or equality between the participants, as well as their proportional attitudes towards the communication (i.e., belief, knowledge, images, etc.).

CONTEXT OF COMMUNICATION

If a theory of properties should claim to be empirically relevant, it is necessary to investigate which cognitive processes underlie the assignment of "appropriateness" in communicative contexts. We should examine the set of goals, beliefs and knowledge, and intentions of the speaker and hearer, as well as their relationship that would establish the type of interaction. The first thing that needs to be established is the "world-situation" at the moment of the speech act. Some types of speech differ in strength according to the general goals of the communication: planning, warning, simulation, recovery, and acting in a "world." We call these situation "world-indices." I claim that in order to deal with this variety of indexed worlds, we should assume that the illocutionary force is a fuzzy set. We will argue this point later on.

<u>Principle 1</u>: The hearer and speaker should be inhabitants of the same "indexed world." They should have the same general goal.

Ex: Recovery versus Simulation, Planning, and Warning.

The goal may be implicitly known, but it should be stated by one of the individuals of the world.

<u>Principle 2</u>: The set of indexed worlds is a partially ordered set, {planning, simulation, warning, acting, recovery}, and the "planning-world" should precede all the other worlds; the recovery-world is the last one.

If a planning-world comes after recovery-world, it refers usually to another "communicative situation," for which the previous situation could be a partial cause.

<u>Principle 3</u>: In planning, we should consider all the possibilities, or in other worlds, the plan should not make the difference between possible truths and necessary and actual truths. This means that if every participant in the planning action builds a "planning-world," the "plan" should be a world accessible from each of those other worlds.

In the following, we will prepare a model logic system stronger than the known S_u, called S_u + A, where the additional axiom (A) $NP_p \supset PN_p$ ensures the existence of the "plan" in the system of "planning-world" accessible from each particular plan. Following that, we will impose some constraints on the universe of discourse of the "planning-world."

The Logical System S_u + A

The basis of S_u + A is as follows:

Primitive Symbols

p,g,r,... = proportional variables

$\sim$,N = monadic operators

$\vee$ = dyadic operators

(,) = brackets

Formation Rules

FR1: A variable standing alone is a wff.

FR2: If α is a wff, so are $-\alpha$ and $N\alpha$.

FR3: If α and β are wff, so is $(\alpha \vee \beta)$.

Definitions

[Def $\wedge$] $(\alpha \wedge \beta)$ = Df $\sim(\sim\alpha \vee \sim\beta)$

[Def $\supset$] $(\alpha \supset \beta)$ = Df $(\sim\alpha \vee \beta)$

[Def $\equiv$] $(\alpha \equiv \beta)$ = Df $((\alpha \supset \beta) \cdot (\beta \supset \alpha))$

[Def $\ni$] $(\alpha \ni \beta)$ = Df $N(\alpha \ni \beta)$

[Def =] $(\alpha = \beta)$ = Df $((\alpha \ni \beta) \wedge (\beta \ni \alpha))$

Axioms

I. (The axiomatization of the propositional calculus)

A_1: $(p \vee p) \supset p$

A_2: $q \supset (p \vee q)$

A_3: $(p \vee q) \supset (q \vee p)$

A_4: $(q \supset r) \supset ((p \vee q) \supset (p \vee r))$

II. $Np \supset p$

$N(p \supset q) \supset (Np \supset Nq)$

III. $Np \supset NNp$

A. $NPp \supset PNp$

Rules

TR1: The rule of (uniform) substitution = the result of uniformly replacing any variable in a thesis by an wff is itself a thesis.

Note: By thesis we mean an axiom or a theorem of the system.

TR2: The rule of Modus Ponens: If α and $(\alpha \supset \beta)$ are theses, so is β.

TR3: The rule of necessitation (N): If α is a thesis, $N\alpha$ is a thesis.

Remark: TR3 should not be confused with the invalid wff $p \supset Np$.

I will present the semantic model for S_u + A without insisting on the semantic models in general, or the model for S_u. (There is a vast bibliography of world logic where further information may be found [ ]).

We define a semantic model for S_u+A as an ordered triple $\langle W, R, V\rangle$, where W is a set of objects, called worlds; R is a binary relation, reflexive and transitive definite over the members of W; and V is a value assignment satisfying the conditions:

(1) For any propositional variable p_q, and for any w_i, which is a member of W, either $V(p_j, w_c) = \alpha$ or $V(p_J, w_i) = 0$.

(2) For any wff, α, and for any $w_i \in W$, $V(\sim\alpha, w_i) = 1$, if $V(\alpha, w_i)=0$. Otherwise, $V(\sim\alpha, w_i)=0$.

(3) For any wffs α and β, and for any $w_i \varepsilon W$, $V((\alpha \vee \beta), w_i)=1$ if either $V(\alpha, w_i)=1$ or $V(\beta, w_i)=1$; otherwise, $V((\alpha \vee \beta), w_i)=0$.

(4) For any wff α, and for any $w_i \varepsilon W$, $V(N\alpha, w_i)=1$, if for every $w_j \varepsilon W$ such that $w_i R w_j$, $V(\alpha, w_j)=1$; otherwise, $V(N\alpha, w_i)=0$.

(5) For any "centralized" world, $w_c \varepsilon W$,

(a) there exists a wff $N\alpha$ such that $V(N\alpha, w_j)=1$ if for any wff α, $V(\alpha, w_j)=0$;

(b) there exists a wff $N\alpha$ such that $V(N\alpha, w_j)=0$ if for any wff α, $V(\alpha, w_j)=0$;

(c) there exists a wff α such that $V(\alpha, w_j)=1$ if for any wff $N\alpha$, $V(N\alpha, w_j)=1$.

(d) there exists a wff α such that $V(\alpha, w_j)=0$ if for any wff $N\alpha$, $V(N\alpha, w_j)=0$.

Condition (5) guarantees that the model distinctions among statements in the "centralized" worlds collapse.

Definition: A wff ,

In the following we will prove the soundness and completeness theorem. Since the system that we proposed is a modification of S_u, to prove that the model system is sound on interpretation, we need only to prove that (A), $NP_p \supset PN_p$ is logically true.

Let us suppose that it is not true, so that $V(NP_p \supset PN_p, w_i =0$. If follows that:

(1) $V(NP_p, w_i)=1$

(2) $V(PN_p, w_i)=0$.

The relation R between worlds is reflexive; consequently,

(3) $V(Np, w_i)=0$

and from this

(4) $V(p, w_j)=0$.

From (1), we have

(5) $V(Pp, w_j)=1$

and from this

(6) $V(p, w_k)=1$.

Continuing on, from (2), because of the transitivity of R, we have

(7) $V(Np, w_k)=0$.

According to the premises of S_u+A model, there exists a world (the "centralized " world) w_c, which is accessible from any other world. It is obvious that this world is w_k, as w_k is the only world accessible from all other worlds. Therefore, we see that w_k is accessible from w_j and, as R is transitive, it is accessible from w_i also. Obviously, it is accessible from itself. We have also seen that neither w_i nor w_j are accessible from every other world; w_i is accessible from only itself and w_j is accessible from w_i and from itself. Therefore, since w_k is a "centralized" world, it follows from (7) that there exists a wff, p, such that $V(p, w_k)=0$. But this contradicts (6), so then $V(NP_p \supset PN_p, w_i)=1$, and the soundness of the system is proved.

In order to prove the completeness of S_u+A, we must show that the model distinctions collapse within maximal consistent sets corresponding to "centralized" worlds.

Let us have a $\Gamma_j \varepsilon \Gamma$ maximal consistent with respect to S_u+A. If Γ_j corresponds to a centralized world in a S_u+A model, then it is either a subordinate, or a subordinate of subordinates of any $\Gamma_i \varepsilon \Gamma$. We have to show, then, that:

(a) if $\beta \varepsilon \Gamma_j$, then $N\beta \varepsilon \Gamma_j$ and $P\beta \varepsilon \Gamma_j$,

(b) if $P\beta \varepsilon \Gamma_j$, then $\beta \varepsilon \Gamma_j$ and $N\beta \varepsilon \Gamma_j$, and

(c) if $N\beta \varepsilon \Gamma_j$, then $\beta \varepsilon \Gamma_j$ and $P\beta \varepsilon \Gamma_j$.

In order to prove (a)-(c), we will utilize the following lemmas [ ]:

<u>Lemma 1</u>: If Γ is maximal consistent relative to a model system s, then for any wff α, neither α nor $\sim\alpha$ are in Γ.

<u>Lemma 2</u>: If Γ is maximal consistent relative to a model system s, then for any wff α, either $\alpha \varepsilon \Gamma$ or $\sim\alpha \varepsilon \Gamma$.

<u>Corollary</u>: Every thesis is in every maximal consistent set.

<u>Lemma 3</u>: If Γ is maximal consistent relative to a model system s, then for any wffs α and β, if $\alpha \varepsilon \Gamma$ and $(\alpha \quad \beta) \varepsilon \Gamma$, $\beta \varepsilon \Gamma$.

Let us prove (a). If $\beta \varepsilon \Gamma_j$, then because $PN(\beta \supset N\beta)$ is a thesis of S_u+A, if follows by the Corollary of Lemma 2 that if $PN(\beta \supset N\beta)$ is in every Γ_i, then it is in Γ_j also. Therefore, by the construction of Γ, there is a subordinate Γ_i such that $N(\beta \supset N\beta)$ is in Γ_c. But because Γ_j is a subordinate of subordinates of any Γ_i, it must be that $\beta \supset N\beta \varepsilon \Gamma_j$. Therefore, by Lemma 3, it follows that $N\beta \varepsilon \Gamma_j$. $\beta \supset P\beta$ is also a thesis of S_u+A, so by the Corollary of Lemma 2, $\beta \supset P\beta$ is in Γ_j and by Lemma 3, $P\beta \varepsilon \Gamma_j$.

Let us now prove (b). If $P\beta \varepsilon \Gamma_j$, then because $PN(P\beta \supset \beta)$ is a thesis of S_u+A, it follows by Lemma 2 that $PN(P\beta \supset \beta)$ is in every Γ_i. Thus, by construction of Γ, there is some subordinate Γ_i such that $N(P\beta \supset \beta) \varepsilon \Gamma_i$. But since Γ_j is a subordinate of subordinates or of a subordinate, then $P\beta \supset \beta \varepsilon \Gamma_j$, and by Lemma 3, $\beta \varepsilon \Gamma_j$. As we have seen in proving (a), $\beta \supset N\beta \varepsilon \Gamma_j$ and by Lemma 3, $N\beta \varepsilon \Gamma_j$.

Finally, let us prove (c). If $N\beta \in \Gamma_j$, then because $N\beta \supset \beta$ is a thesis of S_u+A, we have $N\beta \supset \beta \in \Gamma_j$, and by using Lemma 3, $\beta \in \Gamma_j$. $N\beta \supset P\beta$ is also a thesis of S_u+A, and so $N\beta \supset P\beta \in \Gamma_j$. By Lemma 3, $P\beta \in \Gamma_j$, and the completeness is proved.

What should be known about an action, or a chain of actions, in order to be able to deal with (to communicate) them? I claim that the following three items are required:

1) First, one must tell the state in which the world is in (the situation of the of the world) at the moment when the actions initiate. I call this the initial state.

2) Second, one must tell the state in which the world is when the action is completed. I call this the end state.

3) Third, one must tell the state in which the world would be if the agent (the set of individuals that perform an action)

I call states (1) and (3) together the acting situation. If the world is initially in a state, and no agent interfers, then there is no opportunity for either destroying this state or letting it continue. The states (1), (2), and (3) determine the nature of the action. This means that the nature of action is determined by the acting-situation and the result.

In the notion of an opportunity of action, there is a correlation between an actual state of the world, resulting from the action, and a hypothetical state of the world, which would have been if the agent had not acted. The changes of the states of the world would be described by the operator 'T', called "and next"; and the correlation between the actual state of the world and that which it would be is described by the operator 'I' (instead of). The operators T and I, defined on the set of states of the world, behave exactly in the same way, and by applying them together, we get the "TI-calculus". T and I function exactly as binary connections. We can consider T, I reflexive or sometimes reflexive and transitive. This second case is interesting in its applications (we will see it later).

The Axioms of TI-Calculus

T1. $(p \vee gTr \vee s) \leftrightarrow (pTr) \vee (gTr) \vee (gTs)$

T2. $(pTg) \wedge (pTr) \rightarrow pTg \wedge r$

T3. $p \leftrightarrow pTg \vee \sim g$

T4. $\sim(pTg \wedge \sim g)$

I1. $(p \vee gIr \vee s) \leftrightarrow (pIr) \vee (gIr) \vee (gIs)$

I2. $(pIg) \wedge (pIr) \rightarrow pIg \wedge r$

I3. $p \leftrightarrow pIg \vee \sim g$

I4. $\sim(pIg \wedge \sim g)$

Inference in the calculus proceeds through substitution of formulae for variables, detachment and replacement of the expressions by provable equivalent expressions.

We call the connectives 'T' and 'I' coordinators of the possible states of the world (or of possible worlds if you like). 'T' coordinates the world as it is now, with the world which will be next, and 'I' coordinates the world as it is with an agent with the world as it would be if the agent remained passive.

By agent in this sense we mean the groups of individuals who intentionally and consciously make the decisions of what to do, when, where, how to act. In other words, the agent is the initiator of the action.

The general form from which a description of action may become extracted is "_T(_I_)", where the blanks "_", are filled with the states of the world. Speaking of the "world", we have to take into account the universe of the discourse that is constituted by the elements that participate in the description of the world, as it is and as it could be after a change (catastrophy, disastor of all sorts, etc.). Obviously, the elements that we operate with are those from the real or hypothetical world that are relevant only to the "indexed world" which we are talking about (the

> Principle 4: All the indexed worlds have similar universes of discourses that are not disjoint.

Let us consider that the universe is of width n. There are $2^n x 2^n x 2^n$ (or 2^{3n}) possible ways of filling the blanks with state descriptions. Let s_i, s_j, and s_k be state descriptions (not obligatorily different) in the universe. The expression $s_i T(s_j I s_k)$ is equivalent to a conjunction of n expressions for elementary actions, one elementary action for each of the n elements of the universe. The compound of n elementary actions, distributed to the agent in question, is called a total action. For example, "$a_1 \wedge \sim a_2 T(\sim a_1 \wedge a_2 I \sim a_1 \wedge \sim a_2)$" describes the course of action which an agent chooses when he lets one of the two states vanish and produces the other. If we express it by the conjunction $(a_1 T(\sim a_1 I \sim a_1)) \wedge (\sim a_2 T\ (a_2 I \sim a_2))$, each element of the conjunction describes what we call an elementary action (or omission).

Definition: The succession of total states through which the world passes is called a history. A history tells what happens in the world in which there exists certain agents.

Remark: The history doesn't tell which courses of action the agent chooses at various times. In order to know this, we have to know how the world would have changed from one state to the next had it not been for the agent.

Let us suppose the possible states of the world are 2^n, and, the length of histories being m, the total number of histories is 2^{mn}.

We have spoken only about the case in which we gave one agent. There might be as well a group of individuals carrying out the same actions, working together, deciding together, etc.). Most of the time we do have more than one agent, and these agents can either cooperate or contradict each other. In the following paragraphs, we shall discuss the interaction of agents. The interaction of agents turns out to be very important in the study of communication. The interaction of agents is described by iterating operator I. We then have an expression of the form '_T(_I(_I(_I)))', where the introduction of each 'I' refers to the state of the world in which one agent would act and not the others.

I shall define here the notion of normative system, by which I mean a class of norms which stem from the same "source". This "source" is a set of goals (see Principle 1, which states that the common goals of a set of individuals set them together in the same "universe of discourse" or basis for the "indexed worlds").

Sometimes the "source" can be some authority who issues norms for a group of people, as, for example, in a of a disaster when the president of a country enforces a law by his order only that has to be executed at each level.

Definition: An action, or a chain of actions, is determined in a system s, when it is either permitted or forbidden in this system. This definition brings us back to the external principles of a communication system, namely to the maxim of relation that requires that the content of a communication (the actions required or reported by the communicative set) should be relevant to the goal of the communication.

Definition: A normative system is closed if every action is determined in the system. A system which is not closed is open.

Principle 5: In a stress situation, the system of communication has to be closed. By that I mean that at each level every action is determined by a system of norms of communications.

Remark: It is possible for closed systems to be under complete control.

Remark: We can distinguish between an action that is determined and a state of the indexed world being determined.

Definition: A state of an indexed world is deontically determined in a system if it is permitted or forbidden for this state to exist. In a way, it is the same as stating that the indexed world is under control.

Remark: We have to distinguish between the ontic problem, where the reality of the norms lie and what is required for a norm to exist, and the epistemic problem, which is how we come to know about the existence of norms, where "how we come to know" means how we come to decide, establish, etc. the existing norms.

In the following, I will propose a system of epistemic logic that has as its universe of discourse a system of norms which underlie the communicative system. The individuals participating are the agents defined above, and the type of knowledge that they possess is related to the "quality" of communicational relations, to its efficiency and successfulness.

The subject matter of epistemic logic.

The subject matter of epistemic logic is best viewed as an explanatory model, in terms of which certain aspects of natural language can be understood. This explanatory model may be thought of as bringing out the "depth logic" which underlies the complex realities of the ordinary use of epistemic terms such as "to know," and in terms of which these complexities can be accounted for. It therefore does not represent a proposal to modify ordinary language, but rather an attempt to understand it more fully. But this explanatory model does not simply reproduce what there is to be found in ordinary discourse. As is the case with theoretical models in general. It does not seem to be derivable from any number of observations concerning ordinary language. Epistemic logic cannot concern itself with actual occurent knowledge. It must deal with virtual or implicit knowledge, that knowledge which a knower can in principle come to have, what a knower can in principle determine to be the case in conjunction with what he explicitly or implicitly knows.

Epistemic principles.

An absolutely undisputed principle of epistemic logic is that one cannot know what is false; so

P1) What is known must be the case.

If an individual a knows that a proposition p is the case and did not know that q, then it would be implausible to maintain that he knows that p implies q; some have

P2) What is known to follow from the known is itself known.

We may sometimes suppose that in a given system S and individual a knows all the logical consequences of what he knows; so

P3) What follows logically from the known is known.

We can strengthen the previous concept by dropping the requirement that p implies q be provable in a given system S and requiring instead that

P4) What is demonstratable is known.

If we consider inferences of the form: from p is the case we deduce that an individual a, knows p, by replacing p with a wff of the form Kap, or $\sim$Kap we obtain the following principles:

P5) What is known is known to be known

P6) What is unknown is known to be unknown.

Remark:

The difference between P5) and P6) is that in the last one the individual a must know that the inventory is complete, so that if he does not find P in the inventory, then he will know that he does not know that p.

In the following paragraphs we shall consider some systems of epistemic logic that arise by the embodiment of the principles considered above.

Epistematic systems in axiomatic perspective.

In the construction of the epistemic systems we suppose satisfied the two valued propositional calculus. (PC)

Notations:

1) the propositional variables: p,q,r...
2) the connectives: '$\sim$', '&', 'Ka' (a knows), 'Ba' (a believes)

The other connectives are defined in the usual way. We define epistemic possibility for a by Pa.

'Pap' is read 'it is possible for a to know p'.

We note by '=>' the inferences authorized by the inferences rules. Upper case letters are variables over formulas.

Some Epistemic systems.

I will mention the most widely used systems:

T is PC+ (K1): - Kap $\rightarrow$p

(K2): - Ka(p$\rightarrow$q)$\rightarrow$(Kap$\rightarrow$Kaq)

(K3): - p=>:-Kap

S4 is T + (K4): - Kap$\rightarrow$Ka(Kap)

S5 is T + (K5): - $\sim$Kap$\rightarrow$Ka($\sim$Kap)

The basic notion of a semantical theory is normally the notion of truth. However, given a set of formulas, we are not interested here in determining whether they are true under some particular interpretation, but rather in determining whether they are true under any interpretation at all. Thus, we choose the basic concept of our semantic theory to be satisfiability. If the negation of a formula A is not satisfiable, A is said to be valid. We define the satisfiability of a finite set of formulas (with the epistemic operator) as the capability of being true under some state of affairs.

Possible worlds.

We can think of possible worlds as possible situations in which certain states of affairs obtain, so that certain propositions -- those asserting these state of affairs -- are true. Propositions that characterize possible epistemic worlds are propositions not only about what is objectively the case, but also about what is known or not known in those worlds.

Notations.

We shall use '→' for 'if, then' and '<->' for 'if and only if.' We shall use 'A', 'B', 'A1'. 'A2', etcetra for variables over formulas, and 'w'. 'k', 'm', etcetra for variables over sets of formulas.

We note by S one of the systems under discussion: PC, T, S4, or S5.

S* = {A: *A is provable in S*}

[w] = {A: KA is in w}

<W> = {A: ∼Ka∼A is in w}

w is a PC world <->

1) w is maximal: A is in w or ∼A is in w

2) w is consistent: A is not in w or A is not in w

3) w is a filter: A&B is in w <-> A is in w and B is in w

This definition introduces the idea of a possible world construed as the set of all propositions true in that world rather than as a single conjunctive proposition uniting the above requirements. We can replace condition 3) by the following two requirements:

4) w is closed under MP (modus ponens)

5) PC* is a subset of w

Exercise:

Given 1) and 2), prove the equivalence 3) <-> 4) and 5).

For the ease of notation and for the convenience of refering to the philosophical issues related to the epistemic logic, we introduce a type of possible world, called O-world.

w is an O-world <->

1) w is a PC-world

2) [w] is a subset of w

3) [w] is MP closed

Remark:

The conditions 2) and 3) require the satisfaction of axioms (K1) and (K2).

Condition (A):

If we note by S one of the systems PC, O, T, S4, S5 then

w is an S-world <-> 1) w is maximal, consistent and MP closed

2) S* is a subst of w.

Given the following definitions:

1) A set w is S-consistent <->

[If A1, A2,..., An belong to w

then ~(A1&...&An) does not belong to S*]

2) E(S) = {w: w is maximal and S-consistent}

3) Given an ordering of all formulas, A0, A1, A2, ...Ai, ...,

and given a set w, we define a sequence of sets as follows:

f(S, w, 0) = w

f(S, w, i+1) =

{f(S, w, i) ∪ {Ai}} if f(S, w, i) ∪ {Ai} is S-consistent

{f(S, w, i) ∪ {~Ai}} otherwise.

4) s(S, w) = ∪f(S, w, i) (i >= 0)

and the assumptions:

(C1) PC* is a subset of S*

(C2) S* is MP closed.

We have the following Lemmas:

1) w is S-consistent -> e(S, w) is maximal and S-consistent.

2) w is maximal and S-consistent <->

w is maximal, consistent, and MP closed, and S* is a subset of w.

3) A is contained in S* <-> A is contained in the intersection of E(S).

4) A is contained in S* <-> A is contained in the intersection of

{w: w is maximal, consistent, MP closed and S* is a subset of w}.

5) w is a T-world <-> w is contained in E(T).
6) w is a S4-world <-> w is contained is E(S4).
7) w is a S5-world <-> w is contained in E(S5).

Remark:

The Lemmas 5 - 7, via the lemma 2 constitute the proof for Condition (a) above.

Proof:

Lemmas:

1) α is S-consistent = e(S,α) is maximal and S-consistent.
F Let α be S-consistent. e(s,α) is maximal
by contradiction: e(S,α) - S-consistent
we show that K is S-consistent = K$\cup${F}'S
S-consistent, or K$\cup${$\sim$F} is S-consistent
2) α is maximal and S-consistent <=>
α is $\cup x_1$ consistent, $\cup$p - closed, and S$\rightarrow\varepsilon\alpha$.
[proof from C_1 and C_2]
3) F ε S* (=) F ε Ω m (S).
F f S $\rightarrow$ => false L-2, F ε Ω m (S).
If F $\not\varepsilon$ S$\rightarrow$, then by (C_1) or (C_2), $\sim\sim$F $\not\varepsilon$ S*.
=> {$\sim$F} is S-consistent, by Lemme 1.
ℓ(S,($\sim$F})ε m(S) => for some Kε m(S).
4) F ε S$\rightarrow$ (= ∤ ε Ω { α = α is maximal.
com, up - ilsid, oud S* $\leq$ $\alpha\gamma$.
[=] from 2 oud 3)
5) α is a T-world <=> α ε m CT).
+ if α maximal and T-consistent, then α is e.
T-world since by lemme 2 and lemme 4, m(+) is a T-world structure.
6) α is an Sy-world. (=) α ε m(Sy).
7) α is an S5-world (=) α ε m(S5).

While considering the features (±active), (± consciousness), (± initiative) I propose a separation of the so-called "Agents" into two classes: "Agents" and "Patients." Each of these classes will have three members. We distinguish the "Agents" from "Patients" by the presents of the (+active) in "Agents" and (-active) in "Patients."

The two classes of "Agents" and "Patients" are symetrical so they contain:

a1) Initiating Agents (Ai) or Initiating Patients (Pi), characterized by (+initiative, + consciousness)

a2) Medium Agents (Am) or Medium Patients (Pm), characterized by (+consciousness, - initiative)

a3) Final Agents (Af) or Final Patients (Pf), characterized by (-consciousness and -initiative).

By the feature (+consciousness) I mean not only that the "Agents" or "Patients" are aware of what they do, but also that they know how to do it, and why they do it, etcetra.

The "Final Agent" or "Final Patient," by having consciousness, can act only by being manipulated by an Initial or Medium "Agent."

For the sake of clarity, I name each participant in the following manner: the (Ai)-causitor, the (Am)-agent, the (Af)-instrument, the (Pi)-source, the (Pm)-patient, and the (Pf)-benefactor. The naturalness of these names is obvious; e.g., the (Ai), by having initiative and being active causes events to happen, the (Am), by being active and having consciousness does things, etcetra. I introduce these concepts in order to establish the dynamic relations urging the participants to a "communication act."

These are some other specifications needed:

1) The "Patients" virtually double the "Agents." Under appropriate conditions they can jump from the possible to the active state.

2) I propose to represent the feature (+consciousness) by the epistemic attitude of the individual to the states of the universe of discourse.

3) The feature (+initiative) refers to the choice of a particular action out of several alternatives in a given situation. I will represent

in the language of deontic logic dividing the actions to the "Agent" or "Patient" in a particular situation into three categories: permitted, obligatory, and forbidden.

Let us have the situation P and O and represent persuasion and obligation and let us note the individual by "x" and the action in question by "a".

<u>Definition:</u>

1) $x \varepsilon \{Ai,Pi\}$, iff $Pxa \vee \sim Pxa$;

2) $x \varepsilon \{Am,Pm\}$, iff $Pxa \vee Oxa$;

3) $x \varepsilon \{Af,Pf\}$, iff Oxa.

<u>Remark:</u>

1) The "Agent" or "Patient" (Ai,Pi) has complete freedom of action to such a point that he can break the previous norms and do actions that were not supposed to be done in that particular situation.

2) The "Agent" or "Patient" (Am,Pm) has legally limited freedom of action; e.i., he can perform actions permitted or obligated by the system of norms that is instantiated.

3) The "Instrument" and "Befeniciary" (Af,Pf) can perform only obligatory actions, in other words, they have to do exactly what is drawn for them to do. They do not have any freedom of choice with regard to the action.

<u>Remark:</u>

In the case of Ai and Pi by "freedom to choose" I mean that they must implicitly assume the risk of their action.

An example of this would be; a change of plan in a dangerous situation where one of the individuals decides to act in a different way than it was pre-established.

The epistemic attitude of the individuals participating in an act of communication leeds to the structuring relation of their epistemic universe that represents their state of knowledge about that particular situation.

For this situation I shall give an example of the theory proposed above. Let us imagine a situation in which a group of people are preparing a conspiracy against the president. One of them is an "Agent", (a "cop"), however, who will cause the failure of the conspiracy and the destruction of the group.

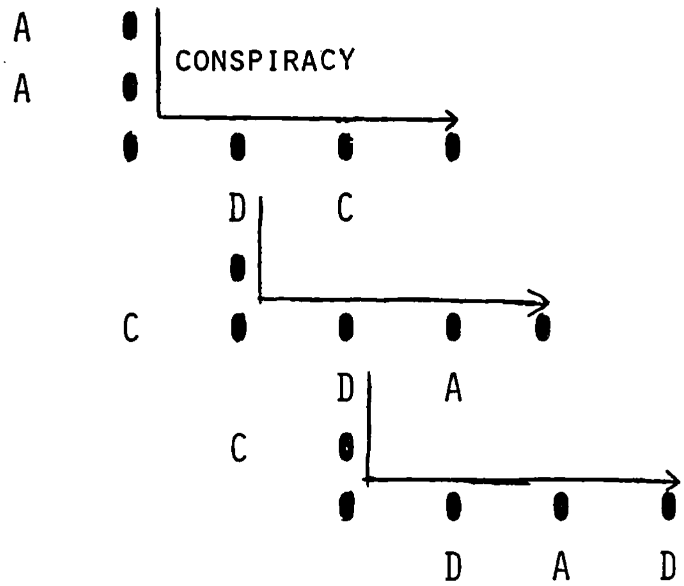
We can break this situation into three specific parts:

1) The "Agents" perceive the goal of this conspiracy. They will use the epistemic rule, (K) $\vdash a => \vdash K x a$ which implies the structuring of this universe, by the epistemic system T. As this stage, the "Agent" is the source of the future destruction of the conspiracy, so he is the (Pi).

The conspirators, who have not observed the spy in their presence, and believe they are safe, plan to act. Ignorant of the spy they don't take and initiative to supress him. It is clear that at this point the conspirators are AM because of the reasons mentioned above. (They can't be Ai as that would solve the problem.)

2) The spy becomes active (he has enough desire to act) and accusses the conspirants. At this point Pi becomes Ai. The president, the target of the conspiracy, is not aware of any of these actions, therefore, he cannot have any initiative. He knows only what the spy tells him, thus, his epistemic universe is structured by an O system. The president, as goal of the conspiracy, is an Af. He changes his status from Pm, the "Patient," who is supposed to support the effect of the conspiracy, to an Af. He is an instrument, manipulated byt the spy who wants to save him. In the next moment Af becomes Am, in other words, an "Agent," who knows of a conspiracy against himself. In his position as president he can order the punishment of the conspirators.

We can see that the spy "Agent" dominates the president by the former's knowledge of the situation. The spy causes the transformation of the conspirators. At the end of the story, the "Agent" as a "Beneficiary" (Pf) reaches a passive state.



A = THE CONSPIRATORS

D = THE AGENT

C = THE PRESIDENT

SECTION VI

TRANSPORTATION SYSTEM FOR CIVIL DEFENSE

TRANSPORTATION SYSTEM FOR CIVIL DEFENSE

In this preliminary report the comparison between the transportation system of a nuclear preparedness system (NPS) and a peacetime preparedness system (PPS) is examined, several problems are discussed, and implications of the transportation system as well as a preparedness system are also examined. In most cases, definite conclusions are avoided and areas where future research is needed are indicated.

Before a comparison of systems is made, the control maps are explained. One control map is of the transportation system of NPS and the other is the transportation system of PPS. They represent that part of the preparedness system in which people are relocated from an area of potential danger to an area of safety, and equipment and supplies are also moved to the host areas. This is not a representation of post-relocation movement nor is it a rescue system.

In each system (peacetime and nuclear), "transportation" is viewed as a function from a certain matrix of data types to another matrix of data types. The rows of the matrices from top to bottom are, respectively, people-place-time, equipment-place-time, and supplies-place-time. In the case of the top row, Transport maps people from a place (call it p_1) at time (t_1) to the triple, people (identical with input) to a place (p_2) arriving at time (t_2), where $p_1 \neq p_2$, and t_2 is later than t_1. Transport acts similarly on the other two rows. Note that Transport does not alter the first column of the matrices; people, equipment, and supplies remain the same, only the places and time change. This is intuitively satisfying.

The primitive functions are fairly obvious. For instance, "AUTO" says that people will travel by automobile from a place at a particular time to a new place at a later time. AIR, RAIL, WALK, BUS, and TRUCK are interpreted similarly. It should be noted that short, perhaps intracity travel by auto, truck, or bus are omitted in the nuclear preparedness control map. So those leaving by air may have been transported by auto to the air terminal, but the auto trip is omitted unless it is longer than some, yet unspecified, distance. However, a control map can be made such that all travel, no matter how short, can be represented.

The data types will need to be specified, but this is work in progress. Roughly, "shelters" mean some sort of protective housing for people, "warehouses" are places where equipment is stored, "distribution points" are structures in which supplies are stored and from which supplies are distributed to shelters. Time has already been given an HOS specification. The meaning of "place" is not yet completely clear. It will have to do with geographic regions from where and to where people, equipment, and supplies are transported. So some places are in risk areas while others are in host areas. Thus, places may contain shelters, warehouses, and distribution points. By "supplies," it is meant food, water, bedding (cots, blankets, pillows, sleeping bags), medical supplies, sanitary supplies, fuel, etc. "Equipment" includes things such as decontaminating devices, tools, trucks, firefighting equipment, certain industrial equipment, etc. Again, "equipment" and "supplies" must be made clear and a specification made explicit. Further discussion of these data types will appear below.

Within an HOS control map, some differences and similarities of the transportation system within NPS and PPS are made explicit. As to be expected, the system in NPS looks more elaborate than the one in PPS. Air and rail transport play a part in one (NPS) while it is absent in the other (PPS). Maybe, more importantly, in the control map for NPS there are multi-transports (transports by auto or truck followed by air or rail) while there are no such moves in PPS. With the exception of those walking to shelters (very small number), all of the transportation of people in response to a natural disaster is by roadways. Depending on the size of the disaster, air and rail may be needed to bring in supplies and equipment. Although much of the travel in response to a nuclear crisis will be by roadways, transportation is not limited to these means. At present, transportation by water is absent for both. The differences will be explained once the data types are fully specified.

The purpose of a transportation system in a preparedness system is to transport people from high risk to low or no risk areas and to transport necessary equipment and supplies to the host areas. Due to the fact that natural disasters are localized to a particular geographical area (in contrast with nuclear attack), the difference traveled between the disaster area and safety (shelter) is generally shorter than the distance traveled in case of nuclear attack. This difference must be captured in the data types of Place. Similarly, time traveled is generally shorter in relocating due to an impending natural disaster than for nuclear attack. Again, this may be handled by additional properties for the data type, Time.

Transportation of people particularly in NPS must not only look at quantity for any given sheltering site, but also at the professions of those being relocated. For example, it must be guaranteed that there will be trained medical personnel (doctors) at all sites. Furthermore, workers who must keep certain industries functioning during the crisis must be transported to the sites of their relocated workplaces and not in shelters too far to commute during the crisis. In PPS, this is not as important, since doctors, for example, can be made available from outside the risk areas. (See "directionality of help" discussion below.)

Another difference that is clear is the type of shelters. The shelters in NPS must have the properties of being blast-resistant and fallout-proof. Thus, the design, construction, and materials used in the construction must be such to satisfy these properties. This contrasts sharply with those shelters, usually relief centers, that are used in PPS. These shelters frequently are no more than church basements, schools (gymnasiums), hotels, or other large buildings that may not qualify as fallout shelters. Also, because natural disasters are localized, the number of people affected are small. So the number and size of shelters (as well as the amount of supplies and pieces of equipment) in PPS will be small as compared with NPS.

Along similar lines, supplies differ within the two systems. In order to cope with fallout, certain number of items such as radiation detectors must be included in NPS. If supplies are prepared in a "kit" form, i.e., a package containing various personal supplies (e.g., blankets, toiletries), then it is important to build such kits in order to avoid having a duplication of articles in supply kits for NPS and PPS. One way to do this would be to construct survival kits containing supplies needed by people in both systems. In addition to these, supplementary kits (with personal radiation detection buttons) should be constructed to be distributed with the basic kits in times of nuclear emergencies. (This procedure rests on the assumption that personal supplies needed in peacetime relocation are needed in nuclear relocation.) Quantity of kits must also be taken into account. Massive evacuations will require kits to be on hand, since production of new ones will be slow or nonexistent.

As mentioned above, the distance over which transportation takes place will be greater in nuclear crisis evacuations. Consequently, air and rail transport will play some role (how large a role is unclear in present literature) in this type of massive relocation. Since the distance from a (natural) disaster area to safety is usually just a few miles and time is short, air and rail transport is not practical in PPS. So multitransports are ruled out. With respect to water travel (barges, private vessels, fishing boats, etc.), it is doubtful that it can prove feasible. Water travel is time consuming. Furthermore, it leads nowhere, i.e., shelters, distribution points, and warehouses are all inland, not along the coast. Travel along the coast would be absurd in times of nuclear crisis. Relocation is away from the coast (risk area), not along it. In the case of inland water travel (e.g., Great Lakes, Mississippi River), the literature is unclear again. Probably very little if any travel would be possible. Many of the major cities along the Great Lakes would be prime target areas, so movement would be away not between them.

Directionality of help is seen to be a difference between the two systems. As areas of the country are evacuated, movement tends to be away from the coasts. Furthermore, in NPS supplies and equipment move in the same direction. However, in a natural disaster movement of people is away from the disaster area and supplies and equipment come to the shelterees from the opposite direction in which the shelterees arrive. With a simplified sketch, in NPS,

$$\begin{bmatrix}\text{People}\\ \text{Supplies}\\ \text{Equipment}\end{bmatrix} \xrightarrow{\text{Transport}} \text{Host area,}$$

where

$$\begin{bmatrix}\text{People}\\ \text{Supplies}\\ \text{Equipment}\end{bmatrix}$$

are in the risk areas and are being transported in roughly the same direction.

In PPS,

$$[\text{People}] \xrightarrow{\text{Transport}} \text{Host areas} \xleftarrow{\text{Transport}} \begin{bmatrix}\text{Supplies}\\ \text{Equipment}\end{bmatrix},$$

where people are leaving the danger area in one direction and from another direction (not within the danger area) the supplies and equipment are transported.

This is worth noting for several reasons. Decisions should be made to build warehouses and distribution points in order to keep a limited amount of supplies outside of potential natural disaster areas such that shipment could be made quickly to these areas in times of emergencies. The location of these warehouses and distribution points besides being outside of potential disaster (natural) areas should be located in the host areas for nuclear crisis. In that way, supplies and equipment leaving the risk areas will be able to use the same structures. This is important to avoid duplication.

Fortunately, the emphasis on natural disaster can be on transportating people from the danger areas since the supplies and equipment are being transportated from safe areas. This is particularly important as time is short in this type of evacuation.

There are several problems which are clear from thinking about transportation in preparedness systems. One which has yet to be formulated is from precisely where are people to leave the high risk areas to be transported to the shelters. In other words, in case of nuclear evacuation, will, say, those leaving by autos (probably the majority), leave from home or from some common point? If people are to leave from home, then a plan to group various homes in some geographical way would be necessary. This puts the emphasis on an evacuation done in stages, i.e., people leaving by area according to a predetermined time. People would not be able to leave according to their own time schedule. To put it another way, people in one area will be instructed to leave at time t_1 and those in another area at time t_2, where $t_1 \neq t_2$. This, of course, should help to futher alleviate congestion on the highways.

The immediate problem with a "brigade" style exodus is that it may cause further congestion within the risk area by having autos meet at one central launch point, unless all other vehicles are kept off the road (except emergency vehicles and service vehicles). Furthermore, even without any congestion, timewise, this appears inefficient. The extra time that would be needed to form a brigade at a meeting point could probably be better spent elsewhere in the relocation procedure.

The literature on the subject of transportation systems and relocation planning fails to mention just how the movement initiates. Nothing explicit is made known on whether or not people leave by autos from home and then drive to shelters (along predetermined routes and times) or leave home by autos, then meeting at a "launch" point (predetermined also) from where the "brigade" drives to shelter. Many choices need to be made.

Equipment and supplies that will be transported (decontamination devices and other equipment may already be stored in the host areas) will leave from warehouses and distribution points in the risk areas. It is also assumed that people, especially those traveling by private auto, will take along some supplies, mostly food. However, due to various car sizes and uneconomical packing, the private transport of supplies is severely limited. Those who travel at least partly by air or rail will be even more limited in what they can take. Thus, most supplies and, in particular, food and water must be brought to the shelters from distribution points in the host areas. But first, food and water must be transported to the distribution points (in the host areas) from stores, manufacturers, and other distribution points in the risk areas. This is worth looking at more carefully.

According to Food System Support of the Relocation Strategy, Vol. I: Analysis and Case Study (Department of Defense, DCPA, 1975), 92 U.S. cities have more than half of their food stocks available locally. Of these cities, only two are not marked as primary nuclear attack target areas. Consequently, these areas must be evacuated. The food in these distribution points must be transported to distribution points in host areas and then on to shelters. This implies that within a host area, there is a class of shelters with an associated system of warehouses, or distribution points or depots from which equipment and supplies are obtained by the relocated population. This appears reasonable since limited movement during a crisis is possible.

The above discussion gives support to the structure of the transport function. People, equipment, and supplies will move from a region (actually different points within the region at certain times) to a host area with the equipment and supplies arriving before or not much after the people have arrived. The operation acting on a matrix and producing a matrix is in some sense natural.

The distribution points may be stocked with some supplies including food, but they cannot meet all the needs of the population of the host area during an attack. Food (especially with short shelf life) must be brought in from the distribution points of the risk areas during the relocation. One item which presents a major problem is water. Due to the weight and the enormous quantity consumed, it is not clear what is the most efficient way of meeting the demands of the relocated population.

In addition to the problems of deciding the best roadway network (the meaning of "best" includes most efficient with respect to time and distance traveled from a region of risk to a region of safety, minimum congestion, and maximum flow), the question of which air or rail terminals that will be used in crisis relocation needs to be examined. The major terminals will be used, but it is not clear just what secondary terminals are to be functioning. Also, there may be an insufficient number of air or rail terms in the host areas.

Trains stopping for passengers at many minor stations would be time consuming. In terms of air traffic, it must be determined which planes are to fly people to shelters or equipment and supplies to their respective destinations. Certain military and commercial airlines (as yet unspecified) will do much of the air transporting. Private planes may transport some but this implies that many small airports are functioning.

The point is that traffic flow along roads by rail and by air remain smooth and major congestions avoided. Besides planning routes, it appears likely that plans should formulate an evacuation by stages. Moreover, a method of removing stopped cars (accident or otherwise) quickly will ensure that highways will not become impassable.

In the case of peacetime transportation, one major difficulty is the shortness of time between threat of disaster and evacuation. In fact, there is generally little or no warning of an impending disaster. In the case of adverse bad weather or flooding, there is just a matter of hours to move people from the area of danger. Until there is some method of predicting earthquakes accurately, evacuation must come after the initial tremors. Thus, the transportation system has to be one that can be put into effect with only a very short notice.

Some consideration should also be made about keeping fuel consumption to a minimum. Fuel must be conserved during relocation so that there will be sufficient quantities for movement during the crisis itself and for postrelocation. Some duel will be stockpiled at distribution points, but this is limited. After a nuclear attack, while some pipelines may not be damaged, the refineries and storage facilities will almost certainly be destroyed.

In the manner in which the transportation system is specified in the control map, an implication is apparent. It is that the time at which the people, equipment, and supplies begin to be transportated are not necessarily dependent on one another. As was mentioned, this may not be entirely correct. The feasibility of a "brigade" must first be fully examined. A brigade system means that a group of people together with a certain amount of supplies and equipment would be transported as one unit to the host area. If this is the case, then the time of departure and the launch point would be the same for all from a particular brigade.

Another possibility is that the times are related in some way but not the place (launch point). In other words, using a system similar to a brigade type, at a particular time or sequence of time, people and their corresponding equipment and supplies begin movement from different points. This transportation system appears to have an advantage over the one above since movement to a common launch point is eliminated, i.e., movement is directed to a host area from the beginning. This, of course, saves time and should certainly not add to any congestion that might already exist.

One major implication of the relocation during a nuclear crisis is the radical change in the economies of the world and, in particular, the country. Immediately upon the issuance of the order for evacuation, the present economic picture would be no longer relevant.

Several problems must be analyzed in detail. One is in what ways can various industries (also, livestock) be protected such that the economies after the crisis will closely resemble the pre-crisis situation. Another concerns economics during the relocation. Finally, what would post-crisis economies be like? To answer this, a realistic post-crisis economies model must be made explicit.

The first of the problems falls partly under the transportation system. During the period of relocation, key industries (not enumerated here) would be relocated in the sense that they will continue to function, at least partially, during the period of relocation. So it would be imperative that the workers (not necessarily all) of these key industries be relocated to the same sheltering area. Some people "who can do the job" may be found living in the host area and that would ease the transportation problem slightly. What is important is that these industries remain vital during and after the crisis. Similarly, equipment and supplies necessary for these industries must be obtainable.

Livestock protection must be taken into account, too. It does not appear feasible to transport livestock during a crisis. Fortunately, a considerable size (figures unavailable) of the U.S. livestock is located in the plain states and not in the more vulnerable coastal regions. The idea of sheltering livestock against fallout should be examined.

As soon as evacuation begins, some sort of plan must be put into action for the monetary system. Banking facilities would be closed or rendered incapacitated by crowds. But will money be necessary at this point? Governmental guidelines may make it possible for people to obtain foodstuffs and personal supplies from local stores (not distribution points or warehouses) on a rationing basis. Order and quickness of such a move must be guaranteed. The question of how goods (food and otherwise) are to be distributed during life in the host areas must be planned. Some sort of rationing system is the most obvious candidate. However, future work will show if such a proposal would be effective, and, if so, how it will operate.

It is far too early to say much about economic life after a nuclear crisis. Needless to say, things will be quite different than before the attack. Shortages will certainly occur, food stored in distribution points will be low (if not depleted), livestock killed, refineries and fuel storage areas destroyed, factories, offices, hospitals, schools also damaged. This and more will put a severe strain on any economic system. However, within certain parameters (not specified here, but will include size of surviving population, extent of damage), an economic model can be constructed. Only after such a model is formulated, can the success of the transportation system be truly evaluated.

As can easily be seen, much work on the transportation system within a preparedness system remains. Hopefully, this report has shown where some problem areas are and how they may be solved. This discussion of problems and implications does not exhaust the possibilities. In fact, it shows that other major systems (e.g., economics) need to be researched so that preparedness systems can be fully specified.

$$\begin{pmatrix} \text{People}, \text{Place}_{\alpha'}, \text{Time}_{\alpha'} \\ \textit{Equipment}, \textit{Place}_{\beta'}, \textit{Time}_{\beta'} \\ \text{Supplies}, \text{Place}_{\gamma'}, \text{Time}_{\gamma'} \end{pmatrix} = \textit{TRANSPORT} \begin{pmatrix} \text{People}, \text{Place}_{\alpha}, \text{Time}_{\alpha} \\ \textit{Equipment}, \textit{Place}_{\beta}, \textit{Time}_{\beta} \\ \text{Supplies}, \text{Place}_{\gamma}, \text{Time}_{\gamma} \end{pmatrix}$$

I N C L U D E

$$\begin{pmatrix} peo_n, & shel_n, t_{2n} \\ equip_n, & ware_n, t_{2n'} \\ sup_n, & dist.pt._n, t_{2n''} \end{pmatrix} = f_n \begin{pmatrix} peo_n, pl_n, t_{2n-1} \\ equip_n, pl_{n'}, t_{2n-1'} \\ sup_n, pl_{n''}, t_{2n-1''} \end{pmatrix}$$

• • •

$$\begin{pmatrix} peo_1, & shel_1, t_2 \\ equip_1, & ware_1, t_{2'} \\ sup_1, & dist.pt._1, t_{2''} \end{pmatrix} = f_1 \begin{pmatrix} peop \\ equ \\ s \end{pmatrix}$$

INCLUDE

$(peo_1, shel_1$

$$\begin{pmatrix} euip_1, & ware_1, t_{2'} \\ sup_1, & dis.pt._1, t_{2''} \end{pmatrix} = f_{n+2} \begin{pmatrix} equip_1, pl_{1'}, t_{1'} \\ sup_1, pl_{1''}, t_{1''} \end{pmatrix}$$

I N C L U D E

$$\begin{pmatrix} equip_r, & ware_r, t_{r+1} \\ sup_r, & dis.pt._{r'}, t_{r'+1} \end{pmatrix} = RAIL \begin{pmatrix} equip_r, pl_r, t_r \\ sup_r, pl_{r'}, t_{r'} \end{pmatrix}$$

$(peo_r, shel_r, t$

$$\begin{pmatrix} equip_j, & ware_j, t_{j+1} \\ sup_j, & dis.pt._j, t_{j'+1} \end{pmatrix} = AIR \begin{pmatrix} equip_j, pl_j, t_j \\ sup_j, pl_{j'}, t_{j'} \end{pmatrix}$$

$$\begin{pmatrix} euip_k, & ware_k, t_{k+1} \\ sup_k, & dis.pt._k, t_{k'+1} \end{pmatrix} = TRUCK \begin{pmatrix} equip_k, pl_k, t_k \\ sup_k, pl_{k'}, t_{k'} \end{pmatrix}$$

$_1$,place$_1$, time$_1$
$_1$,place$_{1'}$,time$_{1'}$
$_1$,place$_{1''}$,time$_{1''}$

$_2$) = f_{n+1} (peo$_1$,pl$_1$,t$_1$)

I N C L U D E

(peo$_k$,shel$_k$,t$_{k'}$) = AUTO(peo$_k$,pl$_k$,t$_k$)

(peo$_j$,shel$_j$,t$_{j'}$) = BUS(peo$_j$,pl$_j$,t$_j$)

,) = WALK(peo$_r$,pl$_r$,t$_r$)

PEACETIME PREPAREDNESS SYSTEM

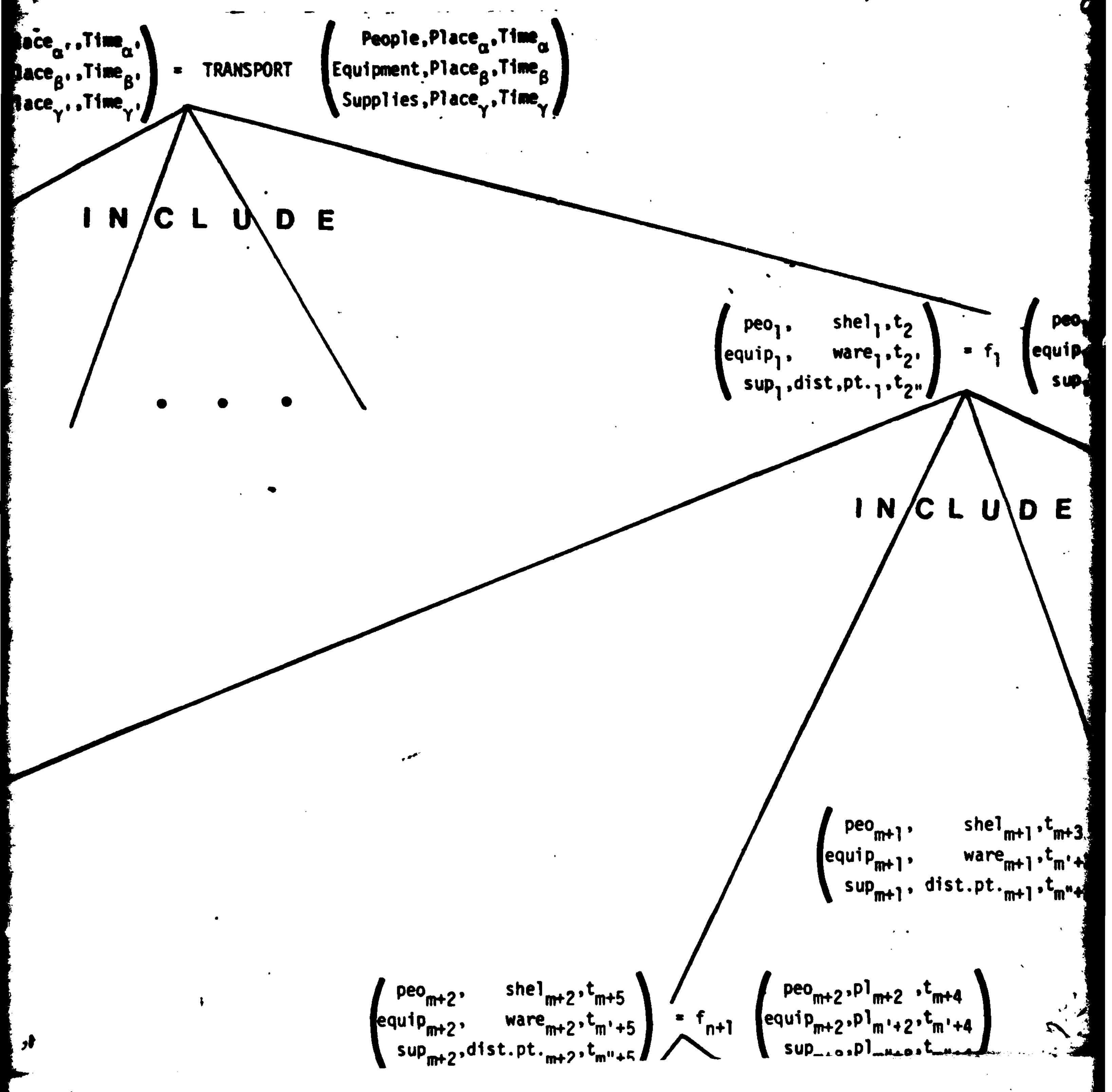
2

NUCLEAR PREPAREDNESS SYSTEM

$$\begin{pmatrix} \text{People},\text{P} \\ \text{Equipment},\text{P} \\ \text{Supplies},\text{P} \end{pmatrix}$$

$$\begin{pmatrix} peo_n, & shel_n, t_{2n} \\ equip_n, & ware_n, t_{2n'} \\ sup_n, & dist.pt._n, t_{2n''} \end{pmatrix} = f_n \begin{pmatrix} peo_n, pl_n, t_{2n-1} \\ equip_n, pl_{n'}, t_{2n-1'} \\ sup_n, pl_{n''}, t_{2n-1''} \end{pmatrix}$$

$$\begin{pmatrix} peo_{m+3}, & shel_{m+3}, t_{m+7} \\ equip_{m+3}, & ware_{m+3}, t_{m'+7} \\ sup_{m+3}, & dist.pt._{m+3}, t_{m''+7} \end{pmatrix} = f_{n+2} \begin{pmatrix} peo_{m+3}, pl_{m+3}, t_{m+6} \\ equip_{m+3}, pl_{m'+3}, t_{m'+6} \\ sup_{m''3}, pl_{m''+3}, t_{m''+6} \end{pmatrix}$$



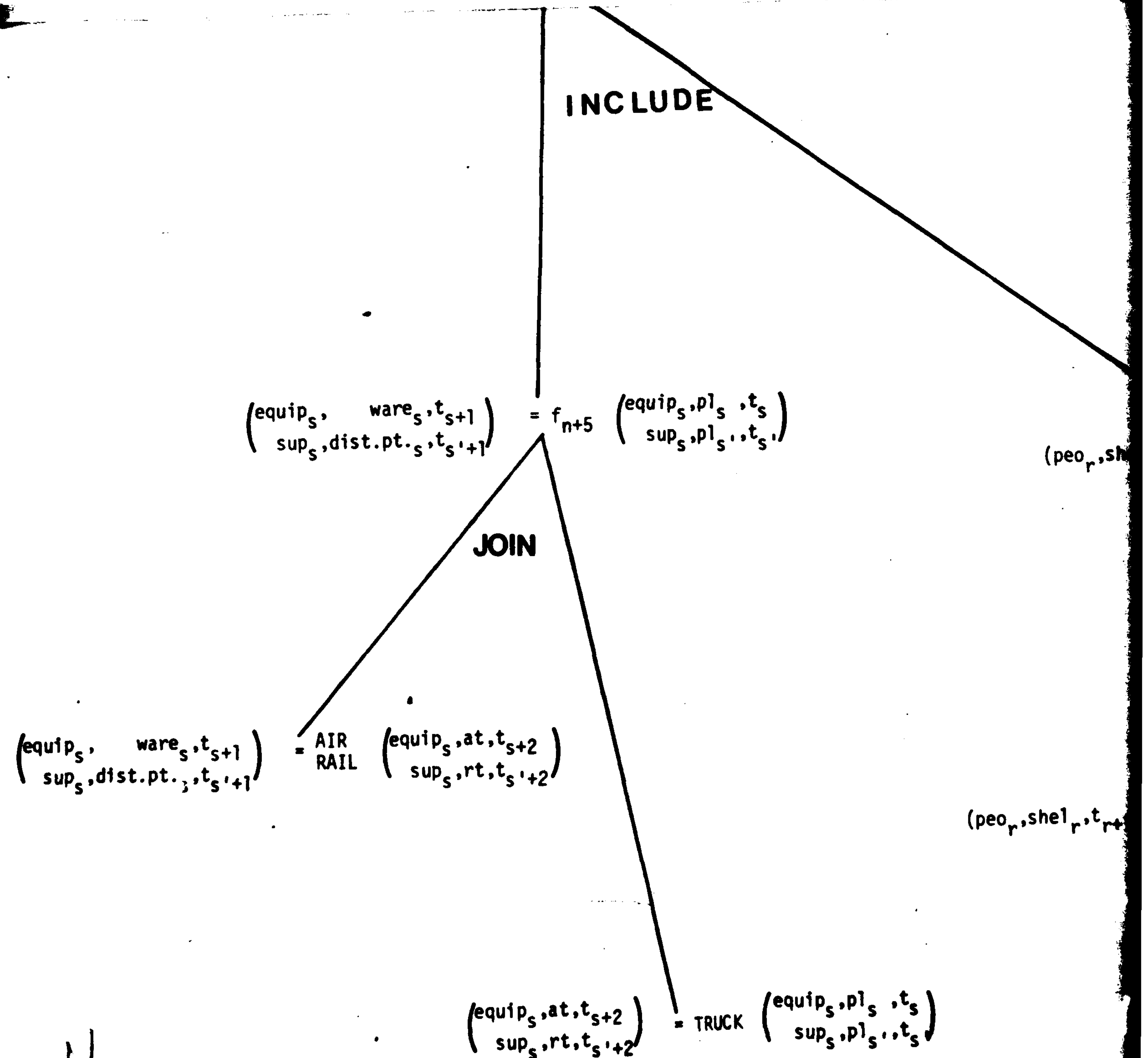
ace, Time, lace, Time, lace, Time
= TRANSPORT
People, Place, Time
Equipment, Place, Time
Supplies, Place, Time
I N C L U D E
peo1, shel1, t2
equip1, ware1, t2,
sup1, dist.pt.1, t2"
= f1
I N C L U D E
peom+1, shelm+1, tm+3
equipm+1, warem+1, tm'+
supm+1, dist.pt.m+1, tm"+
peom+2, shelm+2, tm+5
equipm+2, warem+2, tm'+5
supm+2, dist.pt.m+2, tm"+5
= fn+1
peom+2, plm+2, tm+4
equipm+2, plm'+2, tm'+4

3

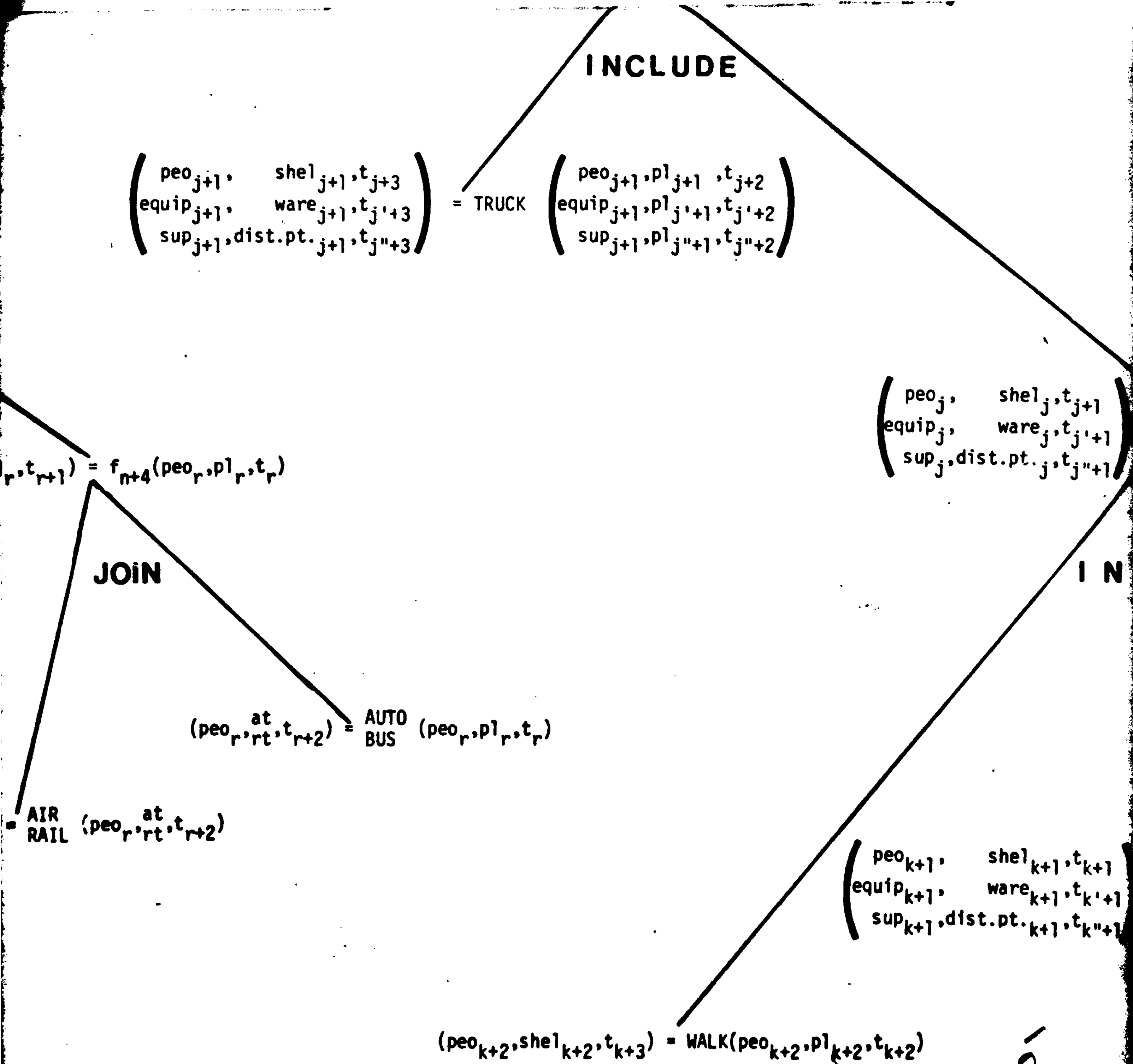
$$\begin{matrix} pl_1 , t_1 \\ pl_{1'} , t_{1'} \\ pl_{1''} , t_{1''} \end{matrix} \Bigg)$$

$$\begin{pmatrix} peo_m, & shel_m, t_{m+1} \\ equip_m & ware_m, t_{m'+1} \\ sup_m, & dist.pt._m, t_{m''+1} \end{pmatrix} = \text{RAIL} \begin{pmatrix} peo_m, rt_m, t_m \\ equip_m, rt_{m'}, t_{m'} \\ sup_m, rt_{m''}, t_{m''} \end{pmatrix}$$

$$= \text{AIR} \begin{pmatrix} peo_{m+1}, at_{m+1}, t_{m+2} \\ equip_{m+1}, at_{m'+1}, t_{m'+2} \\ sup_{m+1}, at_{m''+1}, t_{m''+2} \end{pmatrix}$$


INCLUDE
(equip_s, ware_s, t_s+1 / sup_s, dist.pt._s, t_s'+1) = f_n+5 (equip_s, pl_s, t_s / sup_s, pl_s', t_s')
(peo_r, sh
JOIN
(equip_s, ware_s, t_s+1 / sup_s, dist.pt._s, t_s'+1) = AIR RAIL (equip_s, at, t_s+2 / sup_s, rt, t_s'+2)
(peo_r, shel_r, t_r+
(equip_s, at, t_s+2 / sup_s, rt, t_s'+2) = TRUCK (equip_s, pl_s, t_s / sup_s, pl_s', t_s)

4


INCLUDE
$\begin{pmatrix} peo_{j+1}, & shel_{j+1}, t_{j+3} \\ equip_{j+1}, & ware_{j+1}, t_{j'+3} \\ sup_{j+1}, & dist.pt._{j+1}, t_{j''+3} \end{pmatrix}$ = TRUCK $\begin{pmatrix} peo_{j+1}, pl_{j+1}, t_{j+2} \\ equip_{j+1}, pl_{j'+1}, t_{j'+2} \\ sup_{j+1}, pl_{j''+1}, t_{j''+2} \end{pmatrix}$
$\begin{pmatrix} peo_{j}, & shel_{j}, t_{j+1} \\ equip_{j}, & ware_{j}, t_{j'+1} \\ sup_{j}, & dist.pt._{j}, t_{j''+1} \end{pmatrix}$
$_{r}, t_{r+1}) = f_{n+4}(peo_r, pl_r, t_r)$
JOiN
I N
$(peo_r, \overset{at}{rt}, t_{r+2})$ = AUTO BUS (peo_r, pl_r, t_r)
= AIR RAIL $(peo_r, \overset{at}{rt}, t_{r+2})$
$\begin{pmatrix} peo_{k+1}, & shel_{k+1}, t_{k+1} \\ equip_{k+1}, & ware_{k+1}, t_{k'+1} \\ sup_{k+1}, & dist.pt._{k+1}, t_{k''+1} \end{pmatrix}$
$(peo_{k+2}, shel_{k+2}, t_{k+3})$ = WALK$(peo_{k+2}, pl_{k+2}, t_{k+2})$

51

$$\left.\begin{matrix} ,t_{j+1} \\ t_{j'+1} \\ t_{j''+1} \end{matrix}\right) = f_{n+3} \begin{pmatrix} peo_j, pl_j, t_j \\ equip_j, pl_{j'}, t_{j'} \\ sup_j, pl_{j''}, t_{j''} \end{pmatrix}$$

I N C L U D E

$$\begin{pmatrix} peo_k, & shel_k, t_{k+1} \\ equip_k, & ware_k, t_{k'+1} \\ sup_k, & dist.pt._k, t_{k''+1} \end{pmatrix} = AUTO \begin{pmatrix} peo_k, pl_k, t_k \\ equip_k, pl_{k'}, t_{k'} \\ sup_k, pl_{k''}, t_{k''} \end{pmatrix}$$

$$\left.\begin{matrix} ,t_{k+1} \\ ,t_{k'+1} \\ ,t_{k''+1} \end{matrix}\right) = BUS \begin{pmatrix} peo_{k+1}, pl_{k+1}, t_{k+1} \\ equip_{k+1}, pl_{k'+1}, t_{k'+1} \\ sup_{k+1}, pl_{k''+1}, t_{k''+1} \end{pmatrix}$$

SECTION VII

COMMUNICATION CENTERS LOCATION

COMMUNICATION CENTERS LOCATION

The point of departure of this paper is Clifford E. McClain's paper [1] "Objectives for Preparedness and Their Implications for Civil Defense Design Options," where he gives the functional characteristics of a civil defense system (that is, those end functions of the system that determine its overall worth and effectiveness):

- reduction of the targeting efficiency of the threat,
- good false-alarm tolerance,
- continuity of emergency services, and
- enhanced recovery capability.

If the civil defense system is to function in any adequate strategic sense, it is absolutely obvious that it must satisfy these necessary principles. To define such a system, it is necessary to ensure that efficient communication between the elements of the national civil defense structure be preserved. Once a reliable communication system is designed to meet performance criteria, it is then necessary to study its behavior, efficiency, and reliability in terms of the functional requirements. We consider the functional requirements defined and discussed by Clifford McClain as being the goals of the communication system. The compatability of our communication model with his functional requirements is ensured by both sharing common performance criteria.

In his paper, McClain proposed a probabilistic model; our model is based on a fuzzy approach [2], which can deal effectively with human-based data. The question that we want to answer in this paper is what is a good, efficient way of using the communication centers in a given region by the set of individuals involved in the process of communication? Given the goals of a communication system as defined by the functional requirements, we believe that the location of the communication centers and their accessability is a basic problem towards achieving these goals. We have developed a theoretic model of communication [3], and we intend to study in the future its compatability with the functional characteristics of the civil defense system.

Given a set of individuals and a set of communication centers distributed over a given region, a fuzzy mathematical model is proposed to foresee the clustering of the population in the subsets of individuals using the same communication center. The problem is developed by modeling a fuzzy algorithm of the human-decision process.

We assume that:

1. Each individual has the possibility of communication.
2. Different levels of communication procedures exist, where higher levels indicate more specialized services (i.e., less frequent demand).

Therefore, centers of communication and users are classified in levels with the following qualifications. Any center of communication offers at the same time all the services of a level lower than its own and controls them (HOS control maps). Any user may demand, ask questions and request services up to his own level. It is therefore possible to imagine a mathematical model as a fuzzy algorithm, as follows.

Users choose among all the available communication centers, some which are reasonably located, corresponding to their needs, accessibility requirements, etc. Therefore, communication centers should be located close to the place where the user is located at the moment when he needs to communicate. The further away a communication center is located from the user's location, the more difficult it is for him to use it. In an emergency situation, it is obvious that the individual will wish to minimize any inconvenience. A user would like to satisfy all of his needs, or at least most of them, at the same communication point, but sometimes he can choose to act on different levels. We are considering that his demand for lower-level services is more frequent.

Communication points, reasonably located, can be expressed by associating to each user a fuzzy set of the centers reasonably located. Let us consider first a user who needs to talk to a given level p. His decision is modeled by the product of the fuzzy set of reasonable communication center location by the fuzzy set of not "too crowded" centers. It is important to take into account the degree of "crowdedness", because in the case of a disaster when the problem of relocation is critical, different users, for example, may ask the same communication center to allocate vehicles for transportation.

The decision of the individual as to whom to talk to will be expressed by a fuzzy set over the centers of communication set. The services, or the answers that the user gets, are classified in k levels. A user of level $p \leq k$ asks for an answer up to the level p.

Users are partitioned into a class X of n subsets x, where each subset $x \in X$ contains all the users who are located in the same compact place (that is, geographically at the same place). Each subset x is characterized by a k-dimensional vector (y) whose p'th components gives the number of users belonging to x, whose highest demand level is p. The set of the communication centers is denoted by Y and is assumed to contain n elements y. The set Y is subdivided into k disjoint subsets Y_p (p = 1, 2, ... k) according to the highest level of the type of service (communication) offered. Each communication center y is characterized by a k-dimensional vector C(y), whose p'th component gives the number of users who demand services at the level p from y.

Then, a function $\mu y\ (C(y))$ is given for each $y \in Y$, which gives the membership value of y in the fuzzy set A C Y of the "not too crowded" centers. Then, according to different service levels, the fuzzy set A is partitioned into the fuzzy subsets Ap (p = 1, 2, ... k).

Let B be the fuzzy set contained in X x Y whose elements (x,y) represent a supply communication center y reasonably located with respect to the demand center x. Let $\mu(x,y)$ be the membership function of B.

For $x \in X$, fixed, $\mu(x,y)$ defines over Y the fuzzy set B_x of the communication centers reasonably located with respect to x.

Let us now consider a user of level p belonging to x. For each level $J \leq p$ of his demand, his decision is modeled by the following fuzzy set D_{xpj} with the membership function $\mu_{xpj}(y)$.

$$D_{xpj} = B_x(A_k \cup A_{k-1} \cup \ldots \cup A_p)$$

$$D_{xp(p-1)} = D_{xp1} \quad (B_x A_{p-1}) \quad \alpha; \quad \alpha = \max\mu_x$$

$$D_{xpj} = D_{xp}(j+1) \quad (B_x A_j)\ \alpha \quad \alpha = \max\mu_{xp}(j+1)(y)$$

where AB denotes the algebraic product of the fuzzy sets A and B. ($\mu(y) = \mu_a(y)\ M_b(y)$), A B denotes the union of the fuzzy sets A and B ($\mu(y) = \max\ (\mu_a(y), \mu_b(y))$, and $(A)\alpha$ is the fuzzy set defined by the membership $\mu(y)$ such that

$$\mu(y) = \mu_a(y),\ \mu_a(y) \geq \alpha$$

$$\mu(y) = 0, \qquad {}_a(y) < \alpha$$

Assume that the users of level p apply to y for services of level y ($j \leq p$) with a probability $W_{je}(x,y)$ proportional to μ_{xpj}.

$$W_{jp}(x,y) = \frac{\mu_{xpj}(y)}{\sum\limits_{i=1}^{m} \mu_{xpi}(y_i)} \tag{2}$$

By definition, we assume $W_{jp}(x,y) = 0$ when $j > p$, let $W(x,y)$ be the k x k matrix consisting of the elements $W_{jp}(x,y)$. The vector obtained by

$$W(x,y) \cdot D(x)$$

expresses the expected value of users x of whom apply to y for each "service" level. Therefore the expected value C(y) of all users applying to y is:

$$C(y) = \sum_{i=1}^{m} W(x_i,y)\ D(x_i)$$

$x_i\ \Sigma\ X.$

All these definitions allow us to obtain the solution to the clustering problem.

Discretion (1) requires that the vector C(y) be known in order for it to be possible to compute the membership function of A. (2) C(y) is obtained by __ only at the end of the computation process. The solution could be obtained by the following iterative procedure.

Assume an initial tentative value $C_0(y)$ of the distribution of users among all the centers of communication y, developing the computations from 1 to 4 a new user distribution $C_0{}^1(y)$ is obtained. Therefore, if $C_0(y)$ is equal to $C_0{}^1(y)$, then it represents a problem solution. On the contrary, a new tentative value can be defined

$$C_1(y) = c_0(y) + F[C_0{}^1(y) - C_0(y)]$$

where a suitable small value of F is given the convergence could be proved in the assumption that the infinitesimal variations of the tentative value of C(y) do not produce finite variations of the resulting value $C^1(y)$.

<u>Fuzzy Set of Reasonably Located Centers</u>

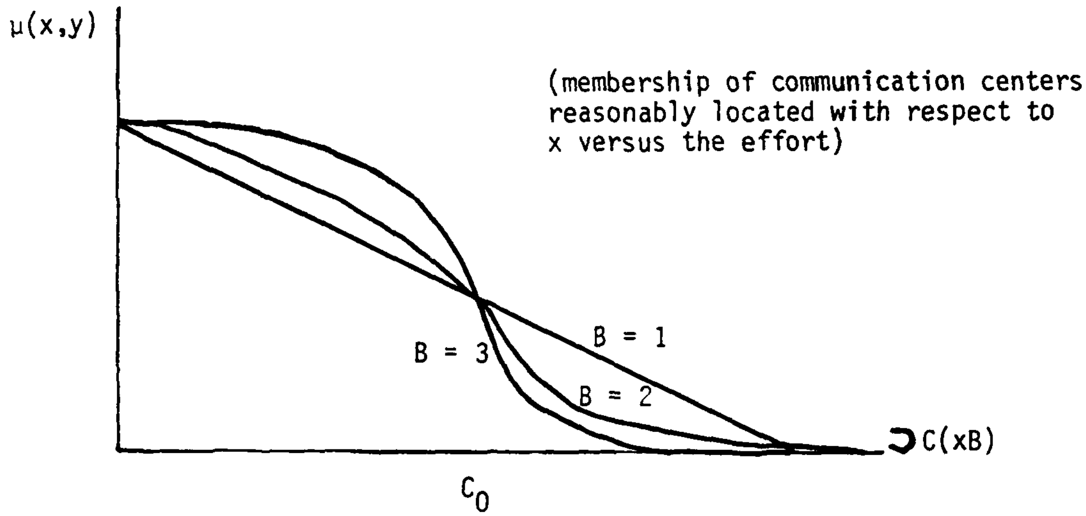
Considering the demand center (point) x and an answering, or service center y, on the basis of good and objective data, the effort, time, money, etc. for operation can be evaluated.

Let C(x,y) be the evalution of the <u>effort</u> (time, money) effected by a user x who used y. The membership $\mu(x,y)$ of the fuzzy set B is defined as a function of C(x,y) depending on parameters that have to be evaluated by considering both the local usages and the effort spent for the considered service.

Therefore, we many consider:

$$(x,y) \quad = \quad p^{-}(\frac{C(x,y)}{C_0})^{B}$$

C_0 is a parameter that evaluates the effort at which membership value is 0.367. It is a scale factor. iB influences the transition rate of the membership from 1 to 0. It allows us to consider the local usages. In fact, larger values of B correspond to a general agreement among users to consider as reasonable "trips" of relatively big effort.



Fuzzy Sets of Non-crowded Communication Centers

Crowded communication center is defined by an individual waiting in a line.

Example: twin evacuation

Two factors have to be considered: (1) the mean waiting time that can be effectively evaluated, and (2) the users impatience, anxiety, etc. depending on the local situation.

Let us have the vector C(y) of the users of a communication center y, and knowing the center capacity, the mean waiting time can be evaluated; let it be $C_t(y)$. The membership of the fuzzy set A can be defined by a function:

$$\mu y(C(y)) = p^{-}\left(\frac{C_k(y)}{C_{k_0}}\right)^{\beta_k}$$

The measuring of C_{k_0} and β_k is as above, but we use different values.

The model is interesting because it models the human behavior by a fuzzy process, and also we consider the "crowding" of the communication centers.

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